University of London

Digitized by the Internet Archive
in 2026

https://archive.org/details/reportsfromcommi0033grea_r5s9

REPORTS

FROM

COMMISSIONERS:

TWENTY-TWO VOLUMES.

—(22.)—

WATER SUPPLY.

Session

10 *December* 1868 —— 11 *August* 1869.

VOL. XXXIII.

1868-9.

REPORTS FROM COMMISSIONERS:

1868-9.

TWENTY-TWO VOLUMES:—CONTENTS OF THE

TWENTY-SECOND VOLUME.

N. B.—*THE* Figures *at the* beginning of the line, *correspond with the* N° *at the foot of each* Report; *and the* Figures *at the* end of the line, *refer to the* MS. Paging *of the Volumes arranged for The House of Commons.*

WATER SUPPLY:

[4169.] Report of the Commissioners on Water Supply - - - p 1

[4169-I.] Minutes of Evidence, February 1867 to December 1868 - 133

[4169-II.] Appendix, Maps, Plans, and Index - - - - - 625

ROYAL COMMISSION ON WATER SUPPLY.

REPORT

REFORM CLUB
PALL MALL

OF

THE COMMISSIONERS.

Presented to both Houses of Parliament by Command of Her Majesty.

LONDON:
PRINTED BY GEORGE EDWARD EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE.

1869.

ORIGINAL COMMISSION.

VICTORIA R.

Victoria, by the grace of God of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith.

To Our right trusty and right entirely-beloved Cousin and Councillor Charles Henry Duke of Richmond; Our trusty and well-beloved Sir John Thwaites, Knight; Henry Drury Harness, Esquire, Companion of Our most Honourable Order of the Bath, Colonel in Our Corps of Royal Engineers; Benjamin Samuel Phillips, Esquire, one of the Aldermen of Our City of London; Thomas Elliot Harrison, Esquire; and Joseph Prestwich, Esquire; greeting.

Whereas We, taking into Our Royal consideration that an ample supply of wholesome water at all times is of essential importance to the health of the population, especially in large towns:

And whereas the present supply delivered in the Metropolis, as well as in many other large towns, has been found insufficient, and is likely to become more so as the population increases, unless some additional sources of supply can be permanently provided:

And whereas a large portion of the water now supplied to the Metropolis and other large towns is drawn from rivers and open streams which pass through populous districts, and are therefore continually exposed to pollution from various causes:

Now know ye, that We have deemed it expedient that a Commission should forthwith issue for the purpose of ascertaining what supply of unpolluted and wholesome water can be obtained by collecting and storing water in the high grounds of England and Wales, either by the aid of natural lakes or by artificial reservoirs at a sufficient elevation for the supply of the large towns, and to report, firstly, which of such sources are best suited for the supply of the Metropolis and its suburbs; and, secondly, how the supply from the remaining sources may be most beneficially distributed among the principal towns.

And further know ye, that We, reposing great confidence in your zeal and ability, have authorized and appointed, and do by these Presents authorize and appoint, you the said Charles Henry Duke of Richmond, Sir John Thwaites, Henry Drury Harness, Benjamin Samuel Phillips, Thomas Elliot Harrison, and Joseph Prestwich, to be Our Commissioners for the purposes aforesaid.

And for the better enabling you to form a sound judgment on the premises We do hereby authorize and empower you, or any three or more of you, to call before you, or any three or more of you, all such persons as you may judge most competent by reason of their situation, knowledge, and experience, to afford you correct information on the subject of this Inquiry.

And it is Our further will and pleasure that you, or any three or more of you, do, with as little delay as possible, report to Us in writing under your hands and seals your several proceedings by virtue of this Our Commission, together with your opinion on the several matters herein submitted for your consideration.

And We will and command that this Our Commission shall continue in full force and virtue, and that you, Our Commissioners, or any three or more of you, may from time to time proceed in the execution thereof, although the same be not continued from time to time by adjournment.

And for your assistance in the execution of this Our Commission, We do hereby authorize and empower you to appoint a Secretary to the said Commission, whose services and assistance We require you to use from time to time as occasion may require.

Given at Our Court at St. James's, the twenty-fourth day of December 1866, in the thirtieth year of Our Reign.

By Her Majesty's command.

S. H. WALPOLE.

NEW COMMISSION.

VICTORIA R.

Victoria, by the grace of God of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith.

To Our right trusty and right entirely-beloved Cousin and Councillor Charles Henry Duke of Richmond, Knight of Our Most Noble Order of the Garter; Our trusty and well-beloved Sir John Thwaites, Knight; Henry Drury Harness, Esquire, Companion of Our most Honourable Order of the Bath, Colonel in Our Corps of Royal Engineers; Sir Benjamin Samuel Phillips, Knight, one of the Aldermen of Our City of London; Thomas Elliot Harrison, Esquire; and Joseph Prestwich, Esquire; greeting.

Whereas We, taking into Our Royal consideration that an ample supply of wholesome water at all times is of essential importance to the health of the population, especially in large towns:

And whereas the present supply delivered in the Metropolis, as well as in many other large towns, has been found insufficient, and is likely to become more so as the population increases, unless some additional sources of supply can be permanently provided:

And whereas a large portion of the water now supplied to the Metropolis and other large towns is drawn from rivers and open streams which pass through populous districts, and are therefore continually exposed to pollution from various causes:

And whereas We did, by Warrant under Our Royal Sign Manual bearing date the Twenty-fourth day of December last, appoint you to be Our Commissioners for the purpose of ascertaining what supply of unpolluted and wholesome water can be obtained by collecting and storing water in the high grounds of England and Wales, either by the aid of natural lakes or by artificial reservoirs at a sufficient elevation for the supply of the large towns, and to report, firstly, which of such sources are best suited for the supply of the Metropolis and its suburbs; and, secondly, how the supply from the remaining sources may be most beneficially distributed among the principal towns.

Now know ye, that We have revoked and determined, and do by these Presents revoke and determine, the said Warrant bearing date the Twenty-fourth day of December last, and every matter and thing therein contained.

And further know ye, that We, reposing great confidence in your zeal and ability, have authorized and appointed, and do by these Presents authorize and appoint, you the said Charles Henry Duke of Richmond, Sir John Thwaites, Henry Drury Harness, Sir Benjamin Samuel Phillips, Thomas Elliot Harrison, and Joseph Prestwich, to be Our Commissioners for the purpose of ascertaining what supply of unpolluted and wholesome water can be obtained by collecting and storing water in the high grounds of England and Wales, either by the aid of natural lakes or by artificial reservoirs at a sufficient elevation for the supply of the large towns, and to inquire into the present Water Supply to the Metropolis, and whether there are other districts in addition to the high districts of England and Wales from which a good supply of unpolluted and wholesome water can

be obtained; and to report, firstly, which of such sources are best suited for the supply of the Metropolis and its suburbs; and, secondly, how the supply from the remaining sources may be most beneficially distributed among the principal towns.

And for the better enabling you to form a sound judgment on the premises We do hereby authorize and empower you, or any three or more of you, to call before you, or any three or more of you, all such persons as you may judge most competent by reason of their situation, knowledge, or experience, to afford you correct information on the subject of this Inquiry.

And Our further will and pleasure is that you, or any three or more of you, do, with as little delay as possible, report to Us in writing under your hands and seals your several proceedings by virtue of this Our Commission, together with your opinion on the several matters herein submitted for your consideration.

And We will and command that this Our Commission shall continue in full force and virtue, and that you, Our said Commissioners, or any three or more of you, may from time to time proceed in the execution thereof, although the same be not continued from time to time by adjournment.

And for your assistance in the execution of this Our Commission, We do hereby authorize and empower you to appoint a Secretary to the said Commission, whose services and assistance We require you to use from time to time as occasion may require.

Given at Our Court at St. James's the Fourth day of April 1867, in the thirtieth year of Our Reign.

By Her Majesty's command.

(Signed) S. H. WALPOLE.

CONTENTS OF THE REPORT.

PAR.

1. Objects of the inquiry.
2. Division of the Report.

PART I.

ON THE PRACTICABILITY OF OBTAINING LARGE SUPPLIES OF WATER FROM THE MOUNTAINOUS DISTRICTS OF ENGLAND AND WALES.

3. Plans for this purpose.

MR. BATEMAN'S PLAN.

4. Date and first publication.

GENERAL DESCRIPTION OF THE SCHEME.

5. Reasons for choice of source.
6. Nature of gathering ground.
7. Conduits to bring the water to London.
8. Reservoirs near London.
9. Distribution of the water in the metropolis.
10. Supply to provincial towns on the way.

EVIDENCE AS TO THE SCHEME.

11. Quantity of water obtainable.
12. Area of gathering ground.
13. Rainfall: Mr. Bateman's estimate of quantity.
14. Objections.
15. Storage reservoirs.
16. Objections.
17. Quality of the water.
18. Influence on this of the nature of the ground.
19. Analyses of water.
20. Objections to the quality:
    (1.) Cultivated land.
21. (2.) Manufactories.
22. (3.) Mineral workings.
23. (4.) Peat.
24. (5.) Action on lead.
25. Estimates of outlay.
26. Justification for the same.
27. Objections to the sufficiency of the estimate.
28. Financial scheme; compulsory rating.
29. Analogy to the Glasgow works.

REMARKS BY THE COMMISSION ON MR. BATEMAN'S PLAN.

30. Introductory.
31. Practicability of the scheme.
32. Uncertainty of estimates of outlay.
33. And of the calculation of income and expenditure.
34. Doubtful economy of the scheme.
35. Pumping would still be required to a considerable extent.
36. On the quality of the water.
37. On the quantity of water obtainable.
38. Probable opposition.
39. Danger of so large a population being solely dependent on one supply.
40. Danger of the collection of such large bodies of water at the head of the Severn valley.

THE CUMBERLAND LAKE SCHEME.

41. Messrs. Hemans and Hassard's plan.
42. Reasons in its favour.
43. General description.
44. Area of the districts.
45. Rainfall, and quantity of water.
46. Storage.
47. Conduit to London.

PAR.

48. Supply to other towns on the way.
49. Proposed additional supply from Bala Lake.
50. Estimate.
51. Financial scheme.
52. Quality of the water.
53. Remarks by the Commission on this scheme.

MR. HAMILTON FULTON'S PLAN.

54. Description.
55. Remarks by the Commission.

MR. REMINGTON'S PLAN.

56. Description and remarks.

MR. DALE'S PLAN.

57. Description and remarks.

REMARKS ON GRAVITATION SCHEMES GENERALLY.

58. Insufficient experience with plans of this kind.
59. Their testing by the long drought of 1868.
60. Their failure in many towns.
61. Causes of this.
62. Irregularity of rainfall.
63. Difficulties with storage.
64. No failure during this drought with the Thames or the Lee.

PART II.

ON SOURCES OF SUPPLY OTHER THAN THE MOUNTAINOUS DISTRICTS OF ENGLAND AND WALES.

65. List of plans involving sources of this kind.
66. *From the Thames or its tributaries.*
67. Mr. McClean's plan.
68. Mr. Bailey Denton's plan.
69. Mr. Brown's proposals.
70. Mr. Bravender's proposals.
71. *From the Lee.*
72. Mr. Mylne's plan.
73. *From the Chalk.* Remarks on this source.
74. Mr. Clutterbuck's suggestions.
75. Mr. Homersham's suggestions.
76. Mr. Barlow's suggestions.
77. Mr. Meeson's suggestions.
78. *Miscellaneous.* Mr. Hennell's scheme.
79. Mr. Ewens' scheme.
80. Mr. Telford McNeil's scheme.
81. Remarks on these various plans.

GENERAL REMARKS ON THE SOURCES AND SPRINGS IN THE THAMES BASIN.

82. Resources of the Thames basin.
83. Illustrative maps.
84. Area, rainfall, average flow, and general features of the Thames basin.
85. Geological sections.
86. General conditions of the subterranean storage.
87. The Tertiary strata.
88. The Chalk.
89. The Greensands.
90. The Wealden strata.
91. The strata overlying the Oolites.
92. The Great and Inferior Oolites.
93. Proportion of the rainfall absorbed by permeable strata.
94. Importance of this condition for the metropolitan supply.

PART III.

ON THE PRESENT WATER SUPPLY OF THE METROPOLIS.

PAR.

95. Early artificial conduits.
96. Morrys's London Bridge waterworks.
97. The New River.
98. Early water companies.
99. Waterworks in the south of London.
100. Extensions and improvements. Introduction of iron street mains.
101. New companies in the west.
102. And in the east and south.
103. Combination to raise the rates. Public inquiry in 1821.
104. Scientific inquiry in 1828 as to the quality of the water.
105. Introduction of filtration.
106. Mr. Telford's plan for new sources.
107. Deterioration of the state of the river.
108. Removal of the Lambeth Company's intake to a point above the tideway.
109. Proposals of the General Board of Health.
110. Chemical Commission of 1851.
111. Metropolis Water Act of 1852.
112. Its provisions.
113. Consequent alterations in the works of the companies.
114. Description of the present arrangements for the supply of London.
115. The New River Company.
116. The East London Company.
117. The Chelsea Company.
118. The West Middlesex Company.
119. The Grand Junction Company.
120. The Lambeth Company.
121. The Southwark and Vauxhall Company.
122. The Kent Company.
123. The Charing Cross well and the Grays' works.
124. General statistics of the water supply.
125. Distribution.
126. Commission on the pollution of rivers. Report on the Thames Conservancy Act of 1866.
127. Report on the Lee. East London Bills. Parliamentary inquiry of 1867.
128. Report of the Committee.
129. River Lee Conservancy Act of 1868.

PART IV.

ON THE SUPPLY OF WATER AVAILABLE FROM THE BASIN OF THE THAMES.

130. Question of the eligibility of the Thames basin as a source of supply for the metropolis.

SECTION I.

AS TO QUANTITY.

131. Reference to the natural features of the basin.
132. Portion of the basin to be considered. Length and course of the river.
133. Rainfall, and quantity flowing off.
134. Volume of the stream at Hampton.
135. Mr. Bateman's views.
136. Views of other witnesses.
137. Minimum volume at present.
138. Quantity of water which the companies are empowered to take.
139. The present minimum quantity may be increased by storage reservoirs.
140. Evidence on this point.
141. Inferences from this evidence.

SUBSIDIARY BASIN OF THE LEE.

142. Present quantity flowing down the river.
143. Evidence on its capacity for increase.
144. Inference.

PAR.

SUBSIDIARY SUPPLY FROM THE CHALK.

145. Evidence on this.
146. Erroneous views.
147. Opinions of the Commission.

Summary.

148. What quantity the Thames basin will yield.

SECTION II.

AS TO QUALITY.

149. Great importance of this subject.
150. Short notice of former improvements.
151. Division of this part of the inquiry.

A.—ON THE PRESENT QUALITY OF THE WATER IN THE THAMES AND ITS TRIBUTARIES.

152. Previous analyses of the water made at various times.
153. Analyses specially made for this Commission.
154. Distinction between inorganic and organic contents.
155. Inorganic contents of Thames water.
156. Cause of hardness.

ON THE HARDNESS OF THE THAMES WATER.

157. General nature of hardness in water.
158. Dr. Clark's test.
159. Hardness of the Thames water.
160. Objections brought against the water on this ground.
161. Effects of hardness on the use of the water for various purposes.
162. General remarks of the Chemical Commission on this subject.

a. EFFECTS OF HARDNESS OF WATER FOR DRINKING PURPOSES.

163. Views of the Board of Health and of the Chemical Commission on this point.
164. Evidence given before this Commission.
165. Opinion of this Commission thereon.

b. FOR CULINARY PURPOSES.

166. Views of the Board of Health.
167. And of the Chemical Commission.
168. Evidence.
169. Opinion of this Commission.

c. FOR WASHING AND FOR MANUFACTURING PURPOSES.

170. Views of the Board of Health.
171. And of the Chemical Commission.
172. Evidence.
173. Opinion of this Commission.

OTHER ELEMENTS OF COMPARISON BETWEEN HARD AND SOFT WATERS. ACTION ON LEAD AND IRON, &C.

174. Action of soft water on lead and iron; its general solvent power. Advantage of water from the present sources in these and other particulars.

ARTIFICIAL SOFTENING.

176. Dr. Clark's softening process ; evidence thereon.
176. Opinion of the Commision.

ON THE ORGANIC IMPURITIES AND CONTAMINATION OF THE THAMES WATER.

177. Difficulty of the subject.
178. How streams become contaminated with organic matter.
179. The Thames waters are so contaminated, but in a less degree than is generally supposed.
180. Beneficial provision of nature for effecting spontaneously the purification of the streams.

Par.
181. Organic matter in water is not always prejudicial: difficulties of estimation by chemical means.

Earlier Analyses.
182. Commissions of 1828 and of 1851 : Hofmann and Blyth's ; Letheby, Odling, and Abel's; Registrar General's returns.
183. Opinions of various witnesses.

Evidence on the Organic Impurities of Thames Water.
184. By chemists and medical men.
185. By engineers and others.

Analyses of the Waters of the Thames and its Tributaries made for the Commission.
186. Remarks by Dr. Frankland and Dr. Odling.
187. Facts observed.
188. Nitrates and nitrites.
189. Organic nitrogen and carbon.
190. Effects of town drainage, and the purifying effect of the flow of the river.
191. The Thames is purer at Hampton than at any other part of its course.
192. Fluctuations in summer and winter.
193. General result of these analyses.
194. Remarks on the statements in the Registrar General's reports.

B.—ON THE FUTURE INFLUENCES LIKELY TO AFFECT THE QUALITY OF THE WATER FROM THE BASIN OF THE THAMES.

195. Probable increase of sewage from towns.
196. Treatment of this subject by the Rivers Pollution Commission.
197. Thames Conservancy Act, 1866, prohibiting the pollution of the Thames.
198. Measures taken under this Act.
199. What benefit may be expected therefrom.
200. Investigation of this by the conservancy board.
201. Evidence on the subject.
202. Investigation by this Commission of the results obtained at Croydon.

WATER FROM THE LEE VALLEY.

203. The same general remarks apply as to the Thames.
204. Report of Rivers Pollution Commission.
205. Cholera in the east of London in 1866.
206. Opinion of the Commons Committee of 1867.
207. River Lee Conservancy Act, 1868.

WATER OF THE KENT COMPANY.

208. Quality good.

FILTRATION.
209. Effectual filtration absolutely essential.
210. Made compulsory by Act of 1852.
211. Neglect of this by the companies.
212. No efficient means of enforcing it under the present system.

GENERAL REMARKS BY THE COMMISSION ON THE QUALITY OF THE WATER FROM THE THAMES BASIN.

213. Qualities of the Thames water, which render it peculiarly suitable for the supply of the metropolis.

On the Organic Impurities.
214. No evidence that the water now supplied by the companies is not generally good and wholesome.
215. Objection raised against it of a less positive character; this objection not well established.
216. Benefits to be expected from the River Conservancy Acts.

Par.
217. General opinion of the Commission.
218. Satisfactory results of the analyses made for the Commission.

PART V.

REMARKS ON VARIOUS POINTS BEARING GENERALLY ON THE SUBJECT OF THE METROPOLITAN WATER SUPPLY.

Section I.

ON THE QUANTITY OF WATER LIKELY TO BE HEREAFTER REQUIRED FOR THE SUPPLY OF THE METROPOLIS.

219. Elements entering into the consideration.

(*a.*) As to the Estimated future Population to be provided for.
220. Present population of London.
221. Views of Mr. Bateman and others
222. Explanatory diagrams.
223. Estimate by the Commission.

(*b.*) Quantity of Water to be allowed for each Individual.
224. General allowance.
225. Evidence.
226. Data as to different towns.
227. Quantity per head already supplied in London.
228. Considerations as to the future.

Estimate of Quantity.
229. Views of the Commission.

Section II.

PROVISIONS AND PROSPECTS OF THE VARIOUS COMPANIES FOR THE FUTURE.

230. Questions to the companies and their answers thereto.
231. Statements as to the various companies.
232. Summary of the whole.

Section III.

ON THE SYSTEM OF CONSTANT SERVICE AT HIGH PRESSURE.

233. Mode of distribution in London.
234. Advantages of the constant service system.
235. Difficulties that would attend its introduction in London.
236. Waterworks Clauses Act, 1847.
237. Views of the Board of Health.
238. Provisions of the Act of 1852.
239. Opinion of the Commons Committee of 1867.
240. Evidence given before the Commission.

Remarks by the Commission.
241. Constant service system ought to be introduced.
242. Difficulties under the present system.
243. How it may be effected.

Compulsory Supply to the Poor.
244. Remarks and Recommendations.

Section IV.

GENERAL CONTROL OF THE WATER SUPPLY.

245. Great importance of this question.
246. Former practice in this respect was to vest the water supply in municipal hands.
247. Evidence on the point.
248. Expediency and advantage of consolidating the water supply under public control.
249. This course the more correct on principle.
250. Compulsory rating would be necessary.

PART IV.

ON THE SUPPLY OF PROVINCIAL TOWNS.

PAR.
251. Instructions to the Commission.
252 Proceedings thereon.
253. Evidence.
254. Mr. Bateman's and Messrs. Hemans and Hassard's proposals.
255. Gathering grounds should be preserved for populations near them.
256. Groups of towns should be provided for.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS.

PAR.
257. Conclusions and Recommendations.
258. As to the plans for obtaining water from the mountainous districts of England and Wales.
259. As to the quantity of water available from the Thames basin.
260. As to the quality of the water from the Thames basin.
261. As to the quantity of water likely to be hereafter required for the supply of the metropolis.
262. As to the system of constant service.
263. As to the general control of the water supply.
264. As to the supply of provincial towns.

REPORT.

TO THE QUEEN'S MOST EXCELLENT MAJESTY.

MAY IT PLEASE YOUR MAJESTY,

WE, the Commissioners appointed by Your Majesty for the purpose of inquiring into the means of obtaining additional supplies of unpolluted and wholesome water for the Metropolis and other large towns, humbly report to Your Majesty as follows.

1. The Commission issued by Your Majesty, and dated the 24th of December 1866, commanded us to ascertain "what supply of unpolluted and wholesome water can be "obtained by collecting and storing water in the high grounds of England and Wales, "either by the aid of natural lakes or by artificial reservoirs at a sufficient elevation "for the supply of the large towns, and to report, firstly, which of such sources are "best suited for the supply of the Metropolis and its suburbs; and, secondly, how the "supply from the remaining sources may be most beneficially distributed among the "principal towns."

A second Commission, dated the 4th April 1867, commanded us also "to inquire "into the present water supply to the Metropolis, and whether there are other "districts, in addition to the high districts of England and Wales, from which a good "supply of unpolluted and wholesome water can be obtained."

2. It will be convenient to divide our Report into six parts.

I. On the practicability of obtaining large supplies of water from the mountainous districts of England and Wales.

II. On other available sources of supply.

III. On the present Water Supply of the Metropolis.

IV. On the supply of water available from the basin of the Thames.
Section I. As to quantity.
Section II. As to quality.

V. Remarks on various points bearing generally on the subject of the Metropolitan water supply.

VI. On the supply of provincial towns.

PART I.

ON THE PRACTICABILITY OF OBTAINING LARGE SUPPLIES OF WATER FROM THE MOUNTAINOUS DISTRICTS OF ENGLAND AND WALES.

3. Our attention was first directed to the question of obtaining large supplies of water from the mountainous districts of England and Wales; and five engineering projects, having this object in view, have been laid before us.

Four of these plans have for their object the supply of the Metropolis, viz.:—

Mr. J. F. Bateman's plan, from the sources of the Severn.

Messrs. Hemans and Hassard's plan, from the lakes of Cumberland and Westmoreland.

Mr. Hamilton Fulton's plan, from the sources of the Wye.

Mr. Remington's plan, from the hills of Derbyshire.

The fifth plan, that of Mr. Dale, proposes to supply various towns in Lancashire and Yorkshire.

It will be our duty to describe these plans, and to remark on some of them at considerable length. We have caused the more important of them to be traced on the map of the rivers of England appended to this Report (Appendix B N.) which has been prepared for our use, under the direction of Colonel Sir Henry James, R.E., by the Ordnance Survey Department. From this map, on which the basins drained by the several rivers are distinguished, and many important levels given, a tolerable conception of the general form of the surface of the country can be obtained.

MR. BATEMAN'S PLAN.

4. The first on the list is that of Mr. John Frederick Bateman, F.R.S., civil engineer, who has constructed some of the largest works for Water Supply in the kingdom.

The plan proposed by this gentleman for supplying the metropolis was first published by him in a pamphlet bearing date November 1865, (which we have reprinted in Appendix E. to this Report,) and it has been more fully developed in evidence given by him before us.

App. E.

General Description of the Scheme.

5. Mr. Bateman proposes to collect water by reservoirs to be formed in the mountainous districts of North Wales, and to convey it by an artificial conduit to London.

He urges that the supply for London ought to be sought where the water is purest, softest, and most abundant, and most secure from injury by any operations of manufacture or agriculture. To obtain these conditions he has considered it necessary to go to mountains of hard and impermeable rock, where little cultivation goes on, where only a scanty population is likely to collect, and where reservoirs for storage could be easily provided. He assumes also, as a further condition, that the necessary quantity should be delivered to London at an elevation from which nearly the whole metropolis could be supplied without pumping.

He considers that the nearest high land fulfilling all these conditions is to be found in North Wales, and that the quantity of gathering ground there available is more than sufficient. He has selected, as the best, certain high drainage grounds lying to the south of Snowdon and to the east of Plynlimmon and Cader Idris, and supplying the head waters of the River Severn.

6. The map marked E (2) shows the districts referred to. The Severn rises on the east slope of Plynlimmon, and a few miles down its course it is joined by five other streams, namely, the Tylwch or Dulas, the Clywedog, the Carno, the Ceryst, and the Tarannon. Mr. Bateman proposes to combine the drainage grounds of these various streams into one district, which is tinted green on the map, and which may be distinguished as the *Southern District.* The waters from this district being collected by intercepting conduits, are to be poured into a main reservoir at Trefeglwys, subsidiary reservoirs being added in other parts of the area.

Mr. Bateman also proposes to appropriate the upper drainage grounds of two other rivers lying more to the north, namely, the Vyrnwy and Banw, whose combined waters flow into the Severn between Welshpool and Shrewsbury. This drainage ground is tinted pink on the map, and may be called the *Northern District.* Its waters are proposed to

be stored in several reservoirs constructed on the various streams, and to be collected at a point above Rhyd y Gro.

Both these districts are stated to be generally favourable for water collection. The ground lies high, the rainfall is large, and the conformation of the country admits of the construction of large reservoirs. The geological structure is favourable for the quality of the water, and Mr. Bateman gives an analysis to show that these waters are, in fact, very pure and remarkably free from mineral matter.

7. Mr. Bateman proposes to convey the water from the two districts by separate conduits, converging to a point of junction at Marten Mere, near Montgomery: from this point the joint volume of water would be conducted southwards by a common aqueduct, which, crossing the Severn near Bridgnorth, and passing near the towns of Stourbridge, Bromsgrove, Henley-in-Arden, Warwick, Banbury, Buckingham, Aylesbury, Tring, Berkhampstead, and Watford, would discharge into large reservoirs proposed to be constructed on the high land near Stanmore, about ten miles north-west of London. The total distance the water would have to be brought to London from the delivering point of either of the districts, would be a little above 180 miles. The aqueduct is designed to be capable of conveying 230,000,000 gallons per day.

The direction of the conduit is shown on the plan marked Appendix E (1), and sections of it in various places are given in the Appendices A Q and A R. It would be chiefly an open canal, lined with masonry, but it would be tunnelled where necessary through the hills, and formed by syphon pipes across the deep valleys.

The heads of the conduit, in the Welsh hills, would be at a height of about 450 feet above the mean sea level, and allowing one foot of fall per mile, the water would be delivered into the reservoirs at Stanmore at about 270 feet above the sea.

8. These reservoirs are shown on the plans marked Appendices A N (1 and 2). 6568–70.
They are designed to contain 2,000 millions of gallons, equal to twenty days' supply at the present rate of consumption.

9. The plan proposed by Mr. Bateman for the distribution of the water in the metropolis is shown on the map, Appendix A N. He would make use, as much as possible, of the existing store reservoirs of the various companies, to which he would convey the water by large main pipes from the great Stanmore reservoirs. He would, 6570–88.
however, re-arrange the distribution, dividing the metropolis into four districts, as shown on the map, conveniently arranged so as to suit the levels of the smaller reservoirs. He would further make such alterations in the service mains as would be necessary to provide for a constant service to all the houses, thus doing away with the present intermittent system.

10. Mr. Bateman states that his aqueduct, in traversing the midland counties, would 269–75.
pass within ten miles of the centre of a very populous country which is probably the most difficult to supply with water of any large manufacturing district in England—namely, Birmingham, Wolverhampton, Dudley, Walsall, and the Staffordshire coal district. He therefore thinks it would be expedient to make provision for supplying these places.

There are many important points to be considered in reference to Mr. Bateman's scheme, and on which we have received a considerable amount of evidence.

Evidence as to the Scheme.

11. With regard to the *quantity* of water which can be procured, Mr. Bateman is of opinion that no distant and expensive plan ought to be entertained which would supply less than 200,000,000 gallons a day; and he thinks such a scheme ought to be capable of further extension, so as to provide ultimately for a still larger supply.

The quantity which can be obtained depends on three elements, namely, the area of gathering ground, the rainfall, and the proportion of the latter which can be collected and stored.

12. The *area* of drainage ground marked out by Mr. Bateman is as follows:— 6561.

	Square miles.
Northern District about - - - - -	104
Southern „ „ - - - - -	100
Total - -	204

He, however, points out that this area is capable of great extension in the same basin, and that, moreover, it would be easy to add other adjacent districts of a similar character included in the basin of the Wye. The map E (2) shows the additions that may thus be made, and which comprise about 183 square miles.

13. The *rainfall* appears to be open to some doubt, no complete system of rain gauges having been kept in the district for a sufficient length of time. Mr. Bateman, therefore, in making his calculations on this point, relies to a great extent on the physical conformation of the country, and on the facts observed in nearly analogous cases.

He considers the conformation of the country favourable to a large rainfall. Taking into account the partial results noted by himself, and those obtained in places where like conditions prevail, Mr. Bateman considers that the rainfall here should be as great as in the highlands of Scotland, and as great as in the lake districts of England, with the exception possibly of a particular locality subject, from peculiar local circumstances, to an excessive amount of rain.

He considers he is justified in estimating the probable *average* rainfall in his district at about 75 inches. But as it does not do to lay out waterworks on an average, he prefers to take the two or three driest consecutive years he can find, and estimates 60 inches for them.

He then comes to the question what proportion of this is available. From long general experience and numerous observations he finds the loss, in such districts, from evaporation and absorption, vary from 9 inches to 16 inches, the smaller loss being where the rocks are the hardest and the declivities the greatest. He takes, as a safe estimate for this district, a mean of 12 inches, which, deducted from 60 inches, leaves 48 inches as the net available produce. But for greater security, he diminishes again this last result by 25 per cent., taking only 36 inches as the estimated available proportion of the rainfall on which to base his calculations. He states that this is only three inches more than he is actually collecting and storing in the Manchester Waterworks, where he supposes the rainfall is probably little more than half what it is on the Welsh hills.

From the amount of available rainfall is deducted the quantity necessary for affording compensation to the rivers. Mr. Bateman states that the compensation given in the manufacturing districts, (where frequently, in dry weather, every drop of water is impounded in the night and given out in the day,) has usually been about *one-third* of that which can be collected. But for this district he has allowed only *one-fourth*, because it is not a manufacturing district; there are comparatively no mills, and one-fourth would very materially increase the workable volume of the stream.

He remarks that the floods in these districts are enormous, being from 500 to 1,000 times greater than the dry weather flow, and it is from these that the water would be stored for the use of London, and for compensation. By impounding the water the destructive floods would be diminished and the useful volume in dry weather increased, and he adds that this has been the universal result wherever this principle has been applied.

On these grounds, Mr. Bateman arrives at the following quantities:

	Northern District.	Southern District.
Amount estimated at a rainfall of 36 inches, about	148,000,000	144,000,000
Deduct one quarter for compensation for rivers -	37,000,000	36,000,000
Leaving for the available supply - - -	111,000,000	108,000,000

giving about 219,000,000 gallons per day as the gross produce of the two districts, having the areas above stated. But from the facility of increase of area, he has not hesitated, in his subsequent calculations, to assume an available quantity of 300 millions of gallons.

14. Other authorities, whom we have examined, think Mr. Bateman's estimate of quantity and rainfall too high.

Mr. Hawksley, also a civil engineer of great experience in water supply, judging by analogous districts, considers that the average rainfall would not exceed 45 inches over the whole surface. But he remarks it is known to be impossible, by any system of reservoirs that can be constructed, even with large capital, to deal with more than the average of three consecutive years of minimum fall; the minimum year has about one-

third less than the general average, and in the three consecutive driest years the average fall is almost precisely one-sixth less. Hence, deducting one-sixth from 45 inches, there remains 37½ inches, which Mr. Hawksley considers the quantity due to the three minimum years. Then, secondly, the loss by evaporation, &c. over a district like that, part of which is lowland and part highland, he estimates at about 13½ inches, which leaves 24 inches as the quantity of rainfall available, instead of 36 inches as estimated by Mr. Bateman.

Mr. G. J. Symons, who has for several years recorded annually (in a work published by him entitled "British Rainfall") the fall of rain in various parts of the kingdom, and who has given us elaborate evidence bearing on this and other plans, infers from the facts at his disposal, that the mean fall in three successive dry years would be 44 or 45 inches. 467–506. 526–45. 2729–30.

The Rev. J. C. Clutterbuck doubts Mr. Bateman's estimate of rainfall, and considers the gaugings of the rivers form the only safe criterion of the amount of water obtainable. 1848–66.

Mr. Rawlinson, civil engineer, believes averages in this respect delusive, and considers that a deduction of one-third should be made from the average, to give the minimum fall. 1427–40.

Mr. Hassard, civil engineer, considers that the conclusions which Mr. Bateman has arrived at from the result of gauges kept during the three wettest months of an exceptionally wet year, are not in accordance with the results of gauges in the immediate locality relative to the fall of three dry years. He is of opinion that a greater rainfall than 42 inches could not be reckoned upon over that drainage area in three successive dry years. 965–78.

Mr. Bateman's answers to these objections may be seen in his evidence. 6485. 6524–39.

15. The *storage* is a matter of much importance, as affecting the quantity of water which can be made available to send off the ground. This storage must be sufficient in capacity to collect and impound the flood waters during heavy rains, so as not only to provide sufficient supplies in the dry portions of the year, but also, to a certain extent, to equalize the product of wet and dry years. The storage room must further be calculated not only for the quantity of water intended to be conveyed away, but also for the additional quantity to be sent down the rivers as compensation. 6615.

There being no natural lakes in the district, Mr. Bateman is obliged to have recourse to the formation of reservoirs on a large scale. App. E. 6513–5.

For reasons given by him he considers that a provision for 120 to 140 days' supply would be sufficient, and on this assumption he proposes to make the following reservoirs:— 6560–63. App. E. 37–52. 109–15.

Northern District.	Cubic feet.
Four reservoirs, total capacity about - -	3,494,000,000.
Southern District.	
Three reservoirs - - - - -	3,215,000,000.

The sites of these will be seen on the map E (2), and further particulars will be found in Appendix E., and in Mr. Bateman's evidence. He states that none of the embankments would be more than 80 feet in height, and they would be placed in situations where either hard impervious clay or the solid rock of the Silurian formation would afford the means of making them perfectly safe and water-tight. Two of these reservoirs would be some miles in length, and one, with an embankment of 75 feet high, would hold 50 per cent. more than the available water of Loch Katrine.

16. Some objections have been brought against this portion of Mr. Bateman's plan. Mr. Hawksley considers the proposed storage insufficient, and that the reservoirs, to provide for the three driest years, ought to store about 170 days' supply. 2483. 2489.

Objections have also been made to the amount of property which must be sacrificed to form the reservoirs, and to the danger which might be apprehended in the valley of the Severn from any accident happening to artificial reservoirs, at such an elevation, and containing such an immense storage of water.

17. Another point of great importance in Mr. Bateman's scheme is the *quality* of the water which it will afford.

He has laid before us some analyses procured by him of samples collected in the district; but as we felt that this was a matter on which it was desirable to have the most positive and unexceptionable data, we determined, with the sanction of the Lords of Your Majesty's Treasury, to carry out an independent investigation, by having the district examined, and samples collected and analysed, by competent persons under our own direction.

It was important, in the first place, that the district should be examined, and the samples collected, by a person accustomed to such matters, and this duty we intrusted to Mr. W. Pole, F.R.S., a civil engineer of experience in water supply. He was instructed to go over the ground and select points where samples might be taken, so as to give a fair idea of the waters of the district; to take such samples and forward them to the chemists for analysis; and to note any observations as to the district generally which might appear worthy of our attention. Mr. Pole's report will be found in Appendix B.

Fourteen samples of water were taken, in different parts of the district, and were submitted for analysis to two chemists of eminence, Dr. Frankland, F.R.S., who is employed by the Registrar General to analyse the metropolitan waters, and Dr. Odling, F.R.S., Professor of Chemistry at St. Bartholomew's Hospital. Their report will be found in Appendix D.

18. The quality of water afforded by any particular gathering ground will depend, in the first place, on the geological structure and mineralogical composition of the rocks; in the second place, on the nature of the surface; and thirdly, on the population, cultivation, and on any accidental circumstances that may affect its purity.

To illustrate the geological and physical features of Mr. Bateman's gathering ground we have caused to be prepared the two maps marked Appendices B A, 1 and 2, the former showing the geology of the district, the latter the elevations of the ground expressed by contour lines. The geological and mineralogical features are favourable; the rocks (almost entirely slates of the Silurian series) are such as are best adapted to preserve the purity of the water falling on them, being practically insoluble, and very little liable to disintegration.

The nature of the surface varies in different parts. In the higher portions it is hilly and steep, the slopes are covered with grass used for cattle and sheep pasture, and the population is very scanty. In descending the valleys cultivation begins, trees appear, and the population increases; while in the lower and flatter parts of the district the land is fertile and well tilled. The latter, however, forms only a small portion of the district, and there is no population beyond that of small villages included in the drainage area.

App. D. 6200-6432. 6433-6484.

19. The analysis of the Welsh waters bears out the anticipation of their quality that might be formed *à priori*, and gives the following results: The quantity of solid contents is very small, varying over the district generally from about $2\frac{1}{4}$ to $4\frac{1}{2}$ grains in the gallon. The waters are extremely soft, their hardness, according to Dr. Clark's test, being generally only 1 or 2 degrees. The organic matter is also small, and there are no traces of any noxious pollution; and so far as could be judged by the samples collected, they were of fair appearance, taste, and aëration.

Mr. Bateman asserts that the water will require no filtration, as the storage in such large reservoirs will sufficiently clear it. He bases this opinion on the general clearness of water in natural lakes.

20. We may briefly allude to five objections which have been made to the Welsh waters on the ground of quality.

The first is to the amount of cultivated land in the lower portions of the district, the manuring of which must, it is said, pollute the water flowing over it. But the analyses do not detect any noxious pollution.

App. B.

21. The second objection is the existence of certain manufactories, the refuse of which is calculated to defile the water. This objection has been examined by Mr. Pole on the ground, and shown to be quite insignificant.

22 The third objection is that the district contains metalliferous veins and mineral workings, principally lead, which, it is urged, must contaminate the streams. This is, at first sight, a formidable objection, on account of the well-known powerful effect of many metallic salts upon the human system. On this account we directed Mr. Pole carefully to examine the facts upon the ground, and his full report on the subject, conjoined with the analysis of the samples he brought away for the purpose, disposes we think effectually of this objection. It is true that there are lead workings in the southern district, and that from many of them suspicious-looking refuse is turned into the streams; but it is found that this refuse contains as a rule no metallic salts soluble in water, and consists only of a detritus formed from the earthy matrix of the ore, generally finely divided quartz or slate, which has been separated by the grinding and washing processes, and is held in

App. B. App. D. 8213-4.

mechanical suspension by the water passing away. This, if admitted into the reservoirs, would soon deposit and leave no pollution in the water; Dr. Frankland even suggests that its presence might be useful, by carrying down organic matter in the process of deposit. Mr. Pole points out that it might be easily prevented from fouling the streams.

23. The fourth objection is in regard to the existence of peat, and its influence on the water. There is a tendency for peat mosses to form and accumulate in mountainous districts, and the brown colour they impart, under certain conditions, to the water issuing from them, is well known. Mr. Pole remarks that in the higher parts of this district patches of peat moss were of frequent occurrence, and that beds of peat of considerable extent were cut and used generally in the neighbourhood for fuel. We believe it is found that in dry weather the streams of such districts, being the produce of springs, remain clear, not taking the peaty tinge; but that in rainy weather, and flood times, when the water permeates and drains through the mosses, an objectionable colouring effect occurs. The majority of the samples collected for the Commission were taken in fine weather, and are reported as clear; but one or two exceptional samples procured during partial floods were highly coloured, being reported as "deep yellow" after standing two days, and leaving a very brown residue on evaporation. App. D. 6203.

Mr. Bateman, from his experience of Loch Katrine, believes that the brown colour of peaty water is lost by exposure to the atmosphere, and argues that the effect of the storage in large reservoirs, and the passage through the long conduit, would have the effect of delivering the water in London perfectly colourless. He has also described to us an ingenious arrangement in the Manchester Waterworks, by which the colourless dry weather discharge of certain streams is separated from the peaty water of floods; but the applicability of this system on so extensive a scale as that necessary for the London supply has been questioned by other witnesses. 134–6. 6657–62. 2510.

Dr. Angus Smith thinks it might be necessary to remove the colour by filtration, but is in doubt how to apply the process. He thinks it cannot always be drunk with impunity, but the only points requiring much attention are the bitter taste and the appearance. 7264. 7214–55.

Dr. Frankland says that the ordinary sand filtration will not remove the colour, and suggests the use of animal charcoal; but he agrees with Mr. Bateman, that by storage in large reservoirs much of the peaty matter would, in all probability, be precipitated. 6203-12.

Dr. Miller thinks peaty water would not be injurious to health, but describes it as at times very disagreeable for drinking purposes. 7059–7124.

Mr. Hawksley is of opinion that in the metropolis it is very necessary that the water should be white water, perfectly clear and colourless, because coloured water would be disagreeable and contrary to the taste of the people. He says soft water is almost necessarily tinted, as it generally comes from moors and from elevated mountain districts, on which there is a large quantity of peat growing, and it is almost impossible to prevent that water acquiring a stain more or less deep. In dry seasons water from these districts may be a good colour, but it is coloured during floods, and these form the great bulk of the supply. 2504–9.

Being asked, If he could choose between the present and soft water for the London supply, which he would prefer? he says, if he could get the water tolerably free from stain he would use the soft water, but if not he would most certainly prefer the white water. He says that peaty water would not be tolerated in London, and instances that its introduction into Liverpool has given rise to much dissatisfaction. Manufacturing towns choose soft water, even if brown, on account of its importance to their trade; but generally, for drinking purposes, the clear, bright, sparkling water is preferred.

Dr. Letheby also states the water from peaty districts would be so frequently tainted and coloured that it would be objectionable, and that Londoners would not drink it. They would prefer a clear, pure, chalk water. 3870–2.

Mr. Simpson objects to the peaty tinge of water brought from certain hilly districts. He says:—"The Severn water at certain seasons is brown as coffee, and it is not a pleasant "water to drink," and he alludes to the colour of the water at Manchester and Liverpool, corroborating Mr. Hawksley, that at the latter place there was a great complaint on this ground. 4685.

24. The fifth objection is one often brought against soft waters, namely, the facility with which they often act on lead.

Drs. Frankland and Odling consider that soft waters do not necessarily act on even bright lead, and that on tarnished lead they seldom act at all. App. D.

1491–8. Professor Way considers that if soft water were used, it would be prudent to guard against its action on lead, by substituting iron for lead pipes.

2671. Dr. Lyon Playfair states that on the intermittent system of supply, with the pipes alternately full and empty, soft water may act upon the lead of the pipes; but if the pipes were always full, as on the constant supply system, there would be very little or almost no risk.

3140–2. Dr. Parkes considers that it would be hazardous if means were not taken to secure the pipes against the action of soft water.

The evidence does not show any instance of injurious effects having resulted from the introduction of soft water into Manchester, Whitehaven, and other towns.

6616. 25. On the important question of cost Mr. Bateman has given us estimates prepared in great detail, having reference to a supply of 230,000,000 gallons per day; but in order to make the outlay gradual, he proposes to divide the execution into four progressive stages, giving—

	Galls. per day.
For the first stage - - - - -	130,000,000
„ second „ - - - - -	170,000,000
„ third „ - - - - -	200,000,000
„ fourth „ - - - - -	230,000,000

The estimates of outlay on the new works for these several stages, including interest on capital expended during the construction of the works, are as follows:—

For the first stage - - - - -	£8,685,006
„ second „ - - - - -	10,571,615
„ third „ - - - - -	10,822,474
„ whole ultimate supply of 230,000,000 gallons per day	11,400,023

These sums include the necessary arrangements for conveying the new supplies to the existing reservoirs, with a view to their distribution by the existing mains, but do not include the purchase of existing works or interests. Mr. Bateman, however, estimates that certain property of the companies, to the value of 1,000,000*l.*, may be disposed of as soon as the supply by gravitation is introduced; and he therefore deducts this, reducing each of the above amounts by that sum.

App. E. 6738–44. 26. Mr. Bateman uses arguments to justify the expediency of such a large outlay for the water supply of London as his scheme would involve. He says, "The amount of "the estimate need not startle the public, for it is not more in proportion, either to the "quantity of water to be obtained, or the ability of the inhabitants to pay for it, than "has been expended in Glasgow, Manchester, Liverpool, and many other towns, while "it is far below the cost incurred by many other towns which could be mentioned."

He gives the following comparative statement of the outlay actually incurred in several large towns for bringing improved supplies of water, including compensation to old companies:—

	Cost for each million of gallons per day.
Liverpool - - - - - - - -	£120,606
Glasgow, for limited supply - - - -	59,200
Do., for full supply - - - -	33,645
Manchester - - - - - -	60,000
London, estimated outlay for limited supply of 130,000,000 gallons -	£165,416
Do., for full supply of 230,000,000 gallons - - -	100,454

But Mr. Bateman considers a fairer test of the ability to pay for water is found in the *assessable value* of respective places, and he gives the following data, calculated in 1865, since which time, however, the rateable value in London has much increased:—

	Total assessable Value.	Assessable Value for Dwelling Houses.
	£	£
Glasgow - - - - -	1,200,000	600,000
Manchester - - - - -	1,200,000	600,000
London - - - - -	15,000,000	10,000,000

From this he reasons that London could bear an outlay for waterworks twelve times as great as Manchester and Glasgow, if measured by the total assessable value, or sixteen times as great if measured by the assessment on dwelling houses alone. And as the outlay in each of the two smaller cities has been something more than 1,500,000*l.*, the proportionate outlay for London would be 19,000,000*l.* on the first principle, and 25,000,000*l.* on the second.

27. Mr. Hawksley doubts the sufficiency of Mr. Bateman's estimate, believing that his reservoirs must be increased in capacity, as before stated.

28. Mr. Bateman developes a financial plan by which he conceives the scheme could be economically carried out, namely, by following the example of the two towns mentioned. App. E.

In each of these towns the waterworks are the property of the corporation, who have the power to levy two rates on account of the water supply, viz.:—

1. A *public rate*, levied in consideration of the protection against fire which "constant supply" and "high pressure" necessarily confer, and in consideration also of the great advantage which all property is supposed to derive from a full supply of water.
2. A *domestic rate*, in respect of the water supplied for domestic purposes.

Both these rates are compulsory rates, levied on all parties, whether they take the water or not. The amounts actually levied at present are:—

	Public Rate.	Domestic Rate.
	In the Pound.	In the Pound.
In Glasgow - - - - -	1*d.*	1*s.* 0*d.*
In Manchester - - - - -	3*d.*	9*d.*
In Liverpool - - - - -	6*d.*	4½*d.*

Mr. Bateman proposes that the water supply of the metropolis should be vested in a public body, who should have power to levy rates of this kind, and who would then proceed to purchase the interests of the several existing water companies, and to introduce the new supply.

29. Mr. Bateman explains that he has been led to the projection of his gigantic scheme by the analogy of the works he has carried out for supplying Glasgow with water from Loch Katrine. For many years the inhabitants of that city, who had previously drawn their supplies from the Clyde, had become uneasy as to the quality of the water, and had anxiously sought for purer sources. In 1853 Mr. Bateman proposed to supply the city by water collected in Loch Katrine, and brought to Glasgow by a conduit 35 miles long. The proposal was at first startling by its magnitude, but after much discussion it was sanctioned and carried out, and the water was delivered from the new source in 1859. Various particulars will be found in the drawing, Appendix A O. 146–58. 176–86.

Emboldened by the success of this work, and acting on the assumption that the metropolis is, or soon will be, in a similar difficulty to Glasgow as regards the supply from its natural river, Mr. Bateman has now brought forward this still bolder scheme. He has sought about, he says, in all directions for a suitable source of supply, and believes that the district he has chosen possesses greater advantages than any other. We may conclude our description with his own words on this point. He says:—

"I may say that I selected this district with a perfect knowledge of what every other part of the country could do. I was aware of the vast quantity of water, and about which there can be no kind of question, in the Lake district, and the elevation of the Lakes; and I knew that those lakes from which water could be obtained were not higher than the sites of reservoirs, which could be formed just as large as lakes, and better than lakes, because you could make them hold more water in the same area in the Welsh hills. Therefore, not only with reference to distance, but with reference to inclination, it was most important to get the water which you wanted at the nearest point. The backbone of England is not only now largely drawn upon by a great many large towns on both sides, in Yorkshire and Lancashire, but it neither possesses the facility for constructing reservoirs, nor the vast amount of rainfall, nor the large area of drainage which for the metropolis is necessary, nor ought it to be tapped, because it is, in fact, the natural resource of all the manufacturing towns in Lancashire and Yorkshire and Cheshire, and therefore the Derbyshire hills and Yorkshire hills were out of the question. The only two districts from which water could be derived were the English lakes and the Welsh hills, without interfering with what might be considered in a national point of view the property 158.

of other districts. But the English lakes, at no greater elevation than the Welsh hills, were at twice the distance, or nearly so.

* * * * * * * * * *

A consideration of all these circumstances (and I gave the whole subject full consideration) determined me in going to the Welsh hills. I saw that there you could get everything nearer, and at an elevation which would enable you to make the works cheaper than in any other part of the kingdom."

Remarks by the Commission on Mr. Bateman's Plan.

30. Having now described the main features of Mr. Bateman's scheme, as presented to us, we proceed to offer some remarks upon it.

31. We are of opinion that Mr. Bateman's plan is practicable in an engineering point of view. The construction of large reservoirs, and the formation of a long conduit, present no problems beyond the ordinary resources of engineering skill, and there are no local or other difficulties to be contended with but such as must be expected to attend works on such a large scale, and such as may with ordinary prudence be surmounted.

32. With reference to the estimates of the cost of these works, as laid before us by Mr. Bateman, we must remark that although he has taken great pains to ascertain the main features of the scheme, sufficiently to establish its practicability, and in some cases by actual survey, yet that detailed surveys and sections of the greater part of the works (the cost of which surveys would probably be not less than 10,000*l.*) have not yet been made. In the absence of such detailed surveys of a scheme involving works of great magnitude, and to some extent novel, and subject to large contingencies and elements of uncertainty, we do not consider that it is possible to arrive at any reliable estimate of the cost which could safely be taken as the basis for recommendation of the scheme.

33. Mr. Bateman, in answer to question No. 6740, has given a calculation of the expected annual income and expenditure, but we are satisfied that there are many points in this calculation which are open to objection or doubt, and we are not able to adopt it.

34. He has also, in answer to question No. 6632, given, in a tabular form, "comparative "estimates of obtaining additional supplies of water from the existing sources and North "Wales," but on examination of the details of these calculations we are of opinion that these estimates are equally open to objections, and Mr. Bateman has not convinced us of the superior economy of the Welsh scheme. He contemplates considerable saving from the consolidation of the management, and from the levying of compulsory rates; but these measures would be equally applicable, and the benefits arising from them equally available, if the present sources of supply were retained.

35. It must be recollected that Mr. Bateman, if his gravitation scheme were introduced, could not entirely dispense with pumping. The high-water level of his Stanmore reservoirs, though 270 feet above ordnance datum, would be less than 200 feet above the ground level of many populous parts of London. And considering the depths to which both the Stanmore and the district reservoirs must of necessity occasionally be drawn down, and the large pressure necessary to force the water through the main and distributory pipes, we doubt whether the head would be sufficient to supply the upper stories of the houses in many parts of London, particularly under the unequal drafts resulting from the system of constant supply. In all these places, therefore, pumping would be required, and this would diminish the advantage assumed for the gravitation scheme.

36. The quality of the water, which appears very similar to that supplied to Glasgow from Loch Katrine, is satisfactory as regards its softness and purity. On other points we consider there are objections.

In the first place it is liable to be coloured by peat. The evidence shows the large presence of peaty matter in the flood samples, and as the great body of the water collected would be in floods and rainy seasons, there seems reason to believe that the coloured condition would be a common one. We agree with the witnesses that coloured water would not be acceptable to the inhabitants of London, for a taint in the water which is visible to every drinker is more likely to be objected to than one which might perhaps be less harmless but less easily seen. We think the question of how far the colour would be lost by storage and in the conduit requires determination by more extended experience;

and it is obvious that the adoption of any system of filtration, if applicable in such a case, would add largely to the original outlay, as well as to the annual cost of the supply.

There is another point requiring serious consideration, namely, the action of soft water on lead, which is often energetic. Of the sixteen samples of Welsh waters collected for the Commission by Mr. Pole, nine were found to act more or less on bright lead, and five to have no action; while on tarnished lead two had considerable action and fourteen had no action. It is true that the introduction of soft water into towns has in this respect often been effected with apparent impunity. The pipes and cisterns soon become coated in a way that, if they are kept full, is thought to preserve them from chemical action. We are, however, told by a very competent witness, that in Manchester "there have been 7268.
"several instances where medical men have believed injurious effects to have been caused "by the lead, and in several cases where there have been lead cisterns the effect has been "very decided indeed; but there have been also several where it has been believed that "the lead poisoning had its origin from the pipes alone,—enough at least to render great "caution necessary." We have had it also stated "that soft waters do not *necessarily* "act on lead." Although, therefore, under a perfectly efficient system of management, or by the substitution of iron for lead, there may be little danger to be apprehended from the use of soft water, still, under the innumerable accidental conditions which must occur in the distribution of a large town supply, arising from repairs of pipes, leakages, carelessness, peculiar states of the water resulting from local causes, and so on, there is no doubt that whilst in hard water the risk of danger is reduced to a minimum, in soft water, on the contrary, the risk must be a maximum one, and one which must always exist.

The circumstance that generally no ill effects have been found to result from the introduction of soft water, is inconclusive against the instance in which it has been affirmed; and unless a very clear and serious case were to occur, many minor cases of slight injury might take place without the cause being suspected.

We shall make some further remarks on the comparative advantages and disadvantages of hard and soft water in a subsequent part of our Report.

37. There is at present an insufficiency of data as to the amount of rainfall in the district, but we are of opinion that the evidence before us tends to show that Mr. Bateman's estimate of it is too high. The rainfall in all districts varies very much in different years, as well as in different parts of the same district, and hence it is only by a long continued and widely extended series of observations on the ground itself that any exact results can be obtained.

Although Mr. Bateman's anticipations on this point may not be fully realized, it must 6701–2.
be borne in mind that he states such a deficiency may be met by taking in a larger area of gathering ground. This appears feasible, the drawback being that it would increase the outlay necessary to be expended.

38. There is every reason to believe that if Mr. Bateman's scheme were ever brought forward in Parliament, it would be subject to a most powerful and determined opposition from interests of various kinds connected with the river and estuary of the Severn.

The Commission has received little or no evidence on this head; for the reason, no doubt, that until the scheme assumes a more practical shape, there is not sufficient inducement to the various parties to come forward.

Mr. Hawksley alludes to some of the points that would be likely to come into dispute, 2460–4.
stating that there are very large interests down the River Severn, from its head to the foot of the estuary, which will be interfered with.

Mr. Simpson corroborates this, and adds that the abstraction of water would be a serious evil, and that considering the great trade and the sums of money that have been spent on the river, it is questionable whether it ought to be interfered with.

It has also been objected that the appropriation of the streams and the loss of the floods would destroy or injure valuable fisheries, particularly of salmon; but on this point we have had no evidence, no one interested in these fisheries having appeared before us.

39. A serious objection has been raised to this as well as to other large schemes for supplying the metropolis from a distance, namely, the danger of having so large a population as that of London and the suburbs dependent solely on one supply of water, which might so easily be stopped by any one of several causes, such as wilful damage, frost, or the failure of any work along the line.

In regard to the first of these causes, we believe anxiety has been felt in other analogous cases. Mr. Hawksley says that this objection has been practically raised by foreign Governments to schemes of his own under similar circumstances.

2527–8.

Mr. Duncan testifies to the anxiety lately felt on this point at Liverpool, and the precautions taken there to prevent interference with the works.

2422–8.

Mr. Hawksley also attaches much importance to the difficulties likely to arise in long-continued cold weather, from frost and snow impeding the current through the long open conduits; and Mr. Muir, the engineer to the New River Company, states that it requires labour and considerable expense in severe frost to keep the New River in efficient flow.

2527–43.

3990–8.

Mr. Bateman, in reply to these objections, says he has provided for ordinary cases of interruption by reservoirs of so large a size near London, that within 10 miles there would be three weeks' storage to cover any interruption from accident or repair. He admits that no provision could be made against the possibility of the water being cut off during hostile occupation or by wilful damage; but this objection is, Mr. Bateman considers, applicable to many large cities; and is a contingency so remote as not to weigh against the many advantages of the plan.

6570.
6643–4.
240–43.

His experience of Loch Katrine aqueduct leads him to attach no great weight to the objection as to freezing, as in a very severe winter, when the temperature fell to 12 and 14 degrees below zero in the open air in the district along which the conduit was carried, the temperature of the Loch Katrine water never fell lower than 39 degrees, and there was not a particle of ice in any shallow or bay in Loch Katrine.

6669–79.

We do not, however, consider the two cases analogous. The great depth of Loch Katrine may maintain a minimum temperature of 39°, but in smaller reservoirs the temperature would necessarily be liable to fall lower. Further, the water after leaving Loch Katrine, having to pass through a tunnel 2,325 yards in length and in places 523 feet below the surface of the ground, and again just before reaching Glasgow passing through another tunnel of 2,640 yards long and 246 feet below the surface, would necessarily have its temperature raised in winter in consequence of the permanent greater heat of the ground at those depths. In the Welsh scheme, on the contrary, there are no deep tunnels; and whereas in the Glasgow works the whole distance of 26 miles was tunnelling or "cut and cover," here there would be nearly 100 miles of open cutting In a river like the Thames the temperature in winter is kept up by the springs which feed it, an advantage an aqueduct does not possess.

The freezing of canals and rivers, even of considerable capacity, in this climate, is a matter of frequent occurrence; and it must be borne in mind that, although the channel may not actually be stopped, the presence of ice and congealed snow in it would seriously diminish the velocity of flow and consequently reduce the quantity of water conveyed.

Then in a conduit of such vast length, and involving engineering works of such great variety and magnitude, it is only reasonable to contemplate the possibility that by some unavoidable mischance, such as a landslip or otherwise, failure or accident might happen to some of the works, which might have the result of stopping the flow for perhaps a considerable time; and in case of repairs being necessary it must be remembered that a large river 180 miles long, with a considerable fall and velocity, would be a difficult thing to deal with.

40. The objection as to the danger of the collection of such vast bodies of water in artificial reservoirs at the head of so important and populous a valley as that of the Severn, derives its principal force from the accidents that have been known to arise, and the destruction of life and property that has ensued from the rupture of reservoirs. And, considering that several large towns and populous and flourishing districts, would all be at the mercy of a flood from one of these gigantic stores of water, and that any failure would be most likely to happen when the store was at the largest, there is no doubt that an accident of the kind would be a great national disaster. In the hands of competent engineers and contractors, with ample funds and time at their disposal, the works may be so substantially constructed as to reduce the risk of such accidents to a remote chance, but we think that, although such an objection ought not to weigh against the plan if it were necessary, it may form an element in the choice between this and other sources of supply.

THE CUMBERLAND LAKE SCHEME.

41. Another plan, somewhat similar to that last described, is brought forward by Messrs. Hemans and Hassard, who propose to supply the metropolis with water from the lakes of Cumberland and Westmoreland.

This plan is described in a pamphlet published by the promoters in July 1866, which we have reprinted in Appendix F., and we have had explanations given by both these gentlemen in their examinations before us.

42. They remark, "It is felt that these suggestions appear somewhat at a disadvantage, App. F.
"particularly as the sources of water supply recommended would seem at first sight to
"demand works in length and extent of greater and more startling magnitude than even
"the already sufficiently bold project of Mr. Bateman, for bringing water to London from
"the Welsh hills at a distance of 183 miles. The sources herein recommended lie at a
"distance of 240 miles from London, but, notwithstanding this increase of distance, we
"believe that when the subject is fully investigated it will appear that our project—
"although involving an apparently larger outlay in the first instance—will, from the
"absolute certainty of the rainfall, the extraordinary purity of the water, the facilities
"afforded by the existing lakes for the construction of the immense reservoirs, and from
"the revenue which may fairly be expected from the sale of water in the districts
"traversed by the aqueduct, be found the best and cheapest which has yet been proposed,
"and that ultimate economy will arise from its selection."

43. The scheme is somewhat complicated in its arrangement, but it will be easily understood from the map, Appendix F (1).

It will be seen that to the north of the great dividing range of hills running east and west between Scaw and Shap fells lie three large lakes, Thirlmere, Ullswater, and Haweswater. These are at a considerable altitude, the level of the water above the sea in each lake being as follows:—

	Feet.
Thirlmere - - - - - -	533
Ullswater - - - - - -	480
Haweswater - - - - - -	694

It is proposed to dam up the outlets of the two higher lakes, so as to raise their levels still further, namely, Thirlmere by 64 feet, and Haweswater by 42 feet.

It is also intended to increase the quantity of water running into them by adding the drainage from the sides of neighbouring hills, to be collected and brought into the lakes by intercepting conduits at proper levels.

The waters from these two lakes would then be conducted by conduits and tunnels into the centre or lower lake, Ullswater, which would be treated as a great distributing reservoir from which the supply would be drawn off as required. This lake has a large drainage of its own, and it is proposed to increase it by a small additional district in the same way as the others.

The natural outlet of the Ullswater lake is at the north end, by the River Eamont, flowing into the Eden, and so by Carlisle into the sea. It is proposed, however, in the present scheme, to tap the lake at its southern end, and to run the water off from it by a tunnel to be formed under Kirkstone Pass, opening out on the slopes of the hills above Windermere, from whence the water would flow by gravitation through a conduit to London.

44. *Area of the Districts.*—The area of the district proposed to be made available as collecting ground is as follows:— App. F. 1.

	Square Miles.
Thirlmere drainage - - - - -	44
Haweswater „ - - - - -	38
Ullswater „ - - - - -	95
Total	177

To this may be hereafter added—

Drainage on the southern slopes of the main range -	53

App. F. 45. *Rainfall and Quantity of Water.*—The lake district having been long noted for its large rainfall, the promoters consider that on this point no difference of opinion can arise.

In the pamphlet (Appendix F.) the promoters state that the observations of the late Dr. Miller, from 1847 to 1853 inclusive, give an average annual fall of 100·56 inches, but 1864 and 1865 being dry years gave only 80·38 inches. They therefore, to avoid question, took the smaller figure 80 inches as the rainfall to be depended on.

606–23. Mr. Hassard, however, in his evidence gives a revised estimate. He says that the three years 1853, 1854, and 1855 were consecutive years of very great drought, the quantity being only about 83 per cent. of the average. These three years give a mean of 64 inches, which therefore he takes as his standard of estimation.

App. F. From the rainfall has to be deducted the loss by evaporation and absorption, which, in a precipitous and rocky district, the promoters assume will be not more than 12 inches. They, however, take it as 14 inches.

The following therefore appears to be their estimate of the quantity to be yielded by the district:—

Area of collecting ground	177	sq. miles.
Mean rainfall of three consecutive dry years	64	inches.
612. Deduct loss by evaporation and absorption	14	„
Available	50	„
This from a drainage area of 177 square miles will give per day about	350,000,000	gallons.
706. Deduct for compensation to rivers a quantity equal to 9 inches of rain over the collecting area	63,000,000	„
Available for supply to metropolis and other towns	287,000,000	„

Mr. G. J. Symons has given us an elaborate report on the rainfall. He considers the evidence in regard to the lake district unusually complete; and he infers from the whole that the true mean rainfall for it may be taken at 77 inches, and the mean of three dry years at 80 per cent. of this, or 61·6 inches. In the driest years he would take something like 66 or 68 per cent. of the average, which would give about 53 inches. During the ten years ending 1859 there was only one drought of more than 40 days' duration, and more than one inch of rain fell during its continuance.

46. *Storage.*—The storage would be obtained principally in Ullswater, Thirlmere, and Haweswater lakes, but partly also from auxiliary reservoirs formed in other places; the raising of Thirlmere and Haweswater, as already described, would allow of a large amount of storage room in them. It is also proposed to raise Ullswater 5 feet, and to draw it down 20 feet when absolutely necessary. It is explained, however, that this would only be required when the maximum quantity was taken, and even then only in very rare cases of extreme drought.

The whole available storage would be about 5,563,000,000 cubic feet, which is equal to 120 days' supply at 250 millions of gallons, or to 157 days' supply at 200,000,000 gallons per day, after giving credit for the average minimum summer yield, and allowing for compensation.

App. F. 47. *Conduit.*—The water would be conveyed from Ullswater to London over a length of 270 miles by conduits, tunnels, and iron pipes.

The work of greatest magnitude connected with the scheme would be the tunnel under Kirkstone Pass, to bring the water southwards from Ullswater. It would be 7¼ miles in length. From the south end of this tunnel the conduit would pass by Ambleside and Kendal, and down the eastern side of Lancashire (avoiding the Wigan coalfield), to the east of Manchester and of the Potteries district, and to the east of the Staffordshire coalfield and of Birmingham, and onwards towards London, following a route
301–2. nearly parallel with that of the London and North-western Railway. The conduit would be in effect equivalent to a river 30 feet wide and 10 feet deep. The inclination taken has
428. been small, viz., 6 inches, and in some cases 4 inches per mile, and for pipes 20 to 24 inches per mile. Probably in some part wrought-iron pipes of 8 feet diameter, lined with cement,

might be used with advantage. Detailed descriptions of these works, and of the nature of the districts over which they are taken, will be found in Mr. Hassard's evidence. The conduit would terminate in a large regulating reservoir to be constructed near Edgeware, at a distance of about 12 miles from Cumberland Gate, Hyde Park. The height of this would be 232½ feet above Ordnance datum, which the promoters consider would ensure an ample pressure for ordinary domestic supply and in case of fire, and would allow of the use of the existing appliances of distribution, which they assume would be destroyed by the use of a much higher pressure and by the adoption of a different system of service. Elevated districts must still be supplied by pumping. The reservoirs are proposed to be in duplicate, containing in the aggregate 15 days' supply at 250,000,000 gallons per day. 733. 743. 730–57. 765–7. 778–817. 823–38. 818–22.

48. *Other Towns on the Way.*—The promoters state that the conduit, in passing through the heart of England, Lancashire, the Potteries, and the midland counties, would be capable of affording *in transitû* a practically unlimited supply of water to the large manufacturing districts and population on the line of its route. They estimate that more than 50,000,000 gallons per day might thus be disposed of.

49. *Additional Supply from Bala Lake.*—The promoters contemplate taking in water from Bala lake, in order to replace water which might be sold to manufacturing towns in the north. This would require an additional aqueduct 70 miles in length, which would join the main conduit at Stoke; and at the point of junction they propose to form an additional reservoir capable of holding about 21 days' supply; they estimate the cost of this addition at 1,500,000*l.*, and the extra quantity obtained at from 50,000,000 to 60,000,000 gallons. 589–604. 884–98.

50. *Estimate.*—The promoters estimated in their pamphlet that the cost of the project complete, for 250,000,000 gallons a day, would be 12,200,000*l.* But in Mr. Hassard's evidence he gives an amended estimate as follows:— App. F. 1060.

Reservoirs, conduits, and works of collection -	£1,013,000
Tunnel under Kirkstone Pass - - -	360,000
Aqueduct to London - - - -	9,806,260
Regulating reservoirs near London - - -	500,000
	£11,679,260
Interest during construction, and other expenses -	1,820,740
	£13,500,000

Mr. Hassard compares this estimate with that for Mr. Bateman's plan, and also with the cost expended for a like purpose in Liverpool, Manchester, and Glasgow, and gives the result as follows, being the cost for each million gallons per day:— 681. 693–9. 718–28. 839–51. 1059. 1060

In Liverpool - - - - - -	£115,115
In Manchester - - - - - -	60,000
In Glasgow, present - - - - -	59,260
,, ultimate - - - - -	33,645
In London, from Wales - - - - -	95,454
,, from lakes - - - - -	88,000

Formidable objections have been raised to these estimates, as will be seen in the evidence. 6703–36.

51. *Financial Scheme.*—Messrs. Hemans and Hassard agree with Mr. Bateman that the water consumers should be the proprietors of the new works; that a compulsory rate should be levied for water supply on all property within the area benefited; and that the existing waterworks should be purchased and incorporated with the new project, and the companies secured in their present incomes. App. E. 910–12.

They give in their pamphlet a statement of estimated income and expenditure, and Mr. Hassard gives amended figures in his evidence.

52. *Quality of the Water.*—The topographical and geological character of the gathering ground is generally similar to that of the Welsh hills, but is in some respects more

favourable, inasmuch as the hills are higher and steeper and less covered with vegetation, and the area contains less population and less cultivated land. Some portions of the district are less favourable than others, but they might, if it were necessary, be excluded.

The two maps, marked Appendices AZ, 1 and 2, have been prepared to show the geological features of the ground, and its elevation at various points above the mean sea level.

There are extensive lead workings in some parts of the district, but the evidence shows that they need not form any objection to the scheme.

We have made an independent investigation of the quality of the water from this district, in the same manner as that from North Wales; the samples were, as in the former case, collected by Mr. Pole and analysed by Drs. Frankland and Odling, and the reports of these gentlemen will be found in Appendices A and D.

The results of the analyses are very similar to those of the Welsh waters as regards softness and purity, and freedom from mineral contents and organic contamination. But the waters are open to the objection mentioned in the former case as regards the probability of their being coloured by peat. The samples generally were taken in fine weather, but many of these were slightly coloured, and two samples that were taken when the streams were in flood were reported to be "yellowish brown, leaving a nearly black residue on evaporation." It is suggested that these waters might be excluded from the collection and used for compensation, but it is probable that they only represent the state that the streams generally would assume in heavy rains, when the water storage would principally take place. The water taken from the lakes was "clear and colourless, leaving a "slightly brown residue on evaporation."

Remarks by the Commission on Messrs. Hemans and Hassard's Plan.

53. This plan has so many points of resemblance to that of Mr. Bateman, that many of the remarks we have made on the Welsh project will be applicable to this also.

The plan is practicable, and has the advantage of the existence of the natural lakes at a high level, but the estimates of cost are more uncertain than in the former case, on account of the less detail in which the promoters have prepared their plans, the greater length of the conduit, (about 90 miles longer than Mr. Bateman's,) and the greater uncertainty as to its exact route and nature.

The quantity of water obtainable is abundant, as the rainfall, whatever may be its exact amount, is admitted on all hands to be very large.

The quality of the water is satisfactory, subject to the same objections that we have mentioned in the Welsh case.

6916–78. 7149–82. There would probably be less formidable opposition to this scheme than to Mr. Bateman's, on account of the less magnitude and importance of the rivers flowing from the district. But the objections from the possible stoppage of the flow in the conduit would be increased in proportion to its greater length.

The remark we have made as to the necessity for pumping to some extent in the Welsh scheme applies with much greater force to this plan, as the promoters propose to deliver the water into the store reservoirs near London at a level 37½ feet lower than Mr. Bateman. This level we believe would be insufficient to supply any but the lower districts, so that pumping would be required over a large portion of the metropolitan area.

There is no doubt that the lake district is a very fine gathering ground for soft water; but it is deserving of consideration that this district is not unlikely to be claimed as the most natural source of supply for large and increasing manufacturing populations in the north of England, for whom soft water would be particularly valuable; and we hold it to be erroneous in principle that any one town or district should take possession of a gathering ground geographically belonging to another, unless it can be clearly shown that circumstances render such a step justifiable.

MR. HAMILTON FULTON'S PLAN.

3446–3571. 4078–4171. 54. The plan proposed by Mr. Fulton is explained in his evidence, and in the two plans in the Appendix marked A A (1 and 2).

He proposes to take water from the upper sources of the River Wye in Mid-Wales. The reasons alleged for the selection of this district are—

3450. "That it is very thinly inhabited, the water at present is scarcely used at all, either for manufacturing, domestic, or navigation purposes; the fisheries which exist can be protected from injury; there are no manufacturing towns in the watershed; and the only application of water for mechanical purposes is for flour mills, of which there are very few."

He also adds—

"The reason why I have chosen the Wye district in preference to any other is, that the importance of the navigation of the Wye is very small, and consequently the abstraction of its water would be no injury as far as the navigation is concerned. Indeed from the sea up to Hereford, which is the largest town in the district, and which has a population of between 15,000 and 16,000 inhabitants only, I believe the trade is nearly extinguished on the river, that is to say, it is nearly superseded by the railway; and the only trade by navigation which exists now is by the canal from the Severn, which runs up to Hereford." 3174.

Mr. Fulton has selected four districts on the Wye and its head tributaries: App. AA.

	Square miles.
No. 1 containing - - - -	146
2 „ - - - -	125
3 „ - - - -	102
4 „ - - - -	67
Total area	440

Reasoning by analogy with the lake district he assumes a rainfall of 60 inches per annum, and that the net quantity after deducting for evaporation and absorption will be 30 inches. 3454–67.

Taking then the highest district, No. 1, with which he proposes to commence, this would give a yield of 175,000,000 gallons. From this he deducts 44,000,000 gallons for compensation to the rivers, which leaves a net quantity of 130,000,000 gallons fro m this district alone. The four districts together are estimated to yield a net average daily supply of 393,000,000 gallons. Six reservoirs are proposed in the first district as shown in the map, the lowest of them being near Rhyader and at a height of 590 feet above the sea. 3500.

From this point there would be a conduit to London 180 miles long. It would be laid first along the valley of the Wye, so as to take in the water of the other and lower districts when required, and passing Glasbury and Hay; and thence it would pass near Kington, Ludlow, Tenbury, Bewdley, Stourport, Bromsgrove, Henley-in-Arden, Warwick, Banbury, Tring, and Watford, to a point near Barnet, eight miles from Hyde Park, where it is proposed to construct a service reservoir at 276 feet above mean sea level. The aqueduct would be 15 feet wide and 14 ft. 6 in. deep with a fall of from 6 to 24 inches per mile, and it is estimated to deliver 230,000,000 gallons per day. 3519–25.

Mr. Fulton has made an approximate estimate of the cost of the first portion of the scheme, viz., to bring 130,000,000 gallons, which amounts to 7,000,000*l*. For 100,000,000 gallons more the cost would be 2,000,000*l*. in addition. 3531–46. 4093–4102.

55. We have had no evidence on this scheme, except from the promoter himself. We consider, however, that from its general similarity to Mr. Bateman's plan it might be further investigated, if any scheme of the kind for the supply of the metropolis should be deemed necessary.

MR. REMINGTON'S PLAN.

56. Mr. George Remington proposes to bring water from the hills of Derbyshire, collecting it at a point above Mill Dale on the River Dove, 586 feet above the sea, and bringing it by a conduit 135 miles long to a reservoir on Barnet Hill, 300 feet above Ordnance datum. 4321–4442.

He proposes to appropriate an area of 262 square miles, and the following extract from his evidence will show his estimate of the quantity of water obtainable—

4335. What quantity of water do you propose to supply per day at Barnet Hill?—About 100,000,000 gallons. I have put it down in the paper which I sent in to the Commission as 83,000,000 gallons, or one-sixth of the rainfall on the 262 square miles, but in round numbers I would take it at 100,000,000 gallons per day.

The rainfall has been gauged at Uttoxeter, which is on the Dove, but Uttoxeter is very low, and there the rainfall is about 30 inches, and I have assumed the quantity falling on the high district to be 48 inches. 4337.

He estimates that his scheme would cost 5,000,000*l*.

In the absence of more complete data we cannot regard this scheme further than in the light of a suggestion, and we need not remark on it more particularly, except to say that this in any case could only form an auxiliary source; while from the proximity of a number of important manufacturing towns we consider such a source should be reserved for their supply, for which it seems well fitted.

MR. DALE'S PLAN.

1061 *et seq.* 57. The last plan for obtaining water from mountainous districts is that of Mr. Thomas Dale, engineer to the Corporation Waterworks of Hull. This plan is described in his evidence before us, and in a pamphlet published by him in 1866.

He proposes to take water from the same sources as Messrs. Hemans and Hassard, namely, from the Cumberland and Westmoreland lakes; but instead of bringing it by an aqueduct to London, he contemplates conveying it by pipes to supply various towns in Yorkshire and Lancashire.

The plans, Appendices Q (1) and Q (2), will give an idea of Mr. Dale's project. It will be seen that he would convey water from Ullswater and Haweswater first to Leeds and various towns in Yorkshire, and then, by a continuation of the conduit, to Liverpool and other towns in Lancashire.

The following is a list of these towns, and the quantities which Mr. Dale's scheme proposes to supply:—

	Gallons per day.
Lancaster	2 millions.
Preston	8 „
Wigan	4 „
Dewsbury	3 „
Wakefield	3 „
Liverpool	40 „
Leeds	15 „
Bingley	1 „
Kendal	2 „
Bolton	8 „
Blackburn	6 „
Keighley	2 „
Bradford	10 „
Huddersfield	4 „
Burnley	4 „
Rochdale	4 „
Halifax	4 „
Colne	1 „
Bury	8 „
St. Helen's	2 „
	131 „

We have already stated, in speaking of Messrs. Hemans and Hassard's scheme, that this is a favourable district for affording water supply to manufacturing districts in the north; but we believe Mr. Dale's proposal to take the water across the backbone of England to the Yorkshire towns a mistake, as they can be well supplied from districts nearer to them. It would, we conceive, be more advantageous to confine the supply from the lakes to the towns and districts lying to the west of the main chain of hills, and to carry the water more directly to them.

REMARKS ON GRAVITATION SCHEMES GENERALLY.

58. The experience with plans for supplying large towns with water by gravitation, from catchment reservoirs formed in hilly districts, has not yet been so extensive as to enable engineers to make accurate calculations, in all cases, as to their sufficiency.

App. BB. Liverpool, for example, was originally supplied by pumping from the red sandstone strata under the town; but some years ago, this source proving insufficient, large works were established for bringing water by gravitation from the Rivington Hills. The supply however proved much less than was expected, the sandstone had again to be resorted to, and now additional sources are required. It was anticipated, on good authority, that a supply of 12 or 13 million gallons per day from the new works might be reckoned on; but our evidence says—

> The Rivington Works are practically a failure as gravitation works; three dry years in succession reduce the available water to six millions of gallons per day, and four successive years of drought, which may very probably occur in future, would reduce it still further; and unless enormous reservoirs or lakes could be made, capable of storing the surplus waters of three or four years; these works must prove insufficient.

At Newcastle-on-Tyne gravitation works were constructed in 1848, but in 1850 the supply failed, and the former establishments for pumping from the Tyne had to be again resorted to. Enlargements of the gravitation works were carried out, but still with insufficient results, and a permanent pumping establishment is now in course of erection.

Bristol was supplied in 1851 by gravitation from the Mendip Hills; in 1864 the supply failed, and after enlarging the works, recourse was had to permanent pumping works from springs nearer the town.

59. During the sittings of this Commission the gravitation plans throughout the country have been subjected to a severe test by the occurrence of an unusually long drought in 1868. Although the rainfall of the whole year was above the average, yet it was very unequally distributed, as from the end of April to the end of September, a period of five months, there was scarcely any rain. Hence the capacities of the catchment reservoirs were severely tested, the towns having to depend entirely on the stores in them, without any feeding supply except that of perennial springs.

We have had evidence on this point from Mr. Bateman, Mr. Hawkesley, and Mr. John Taylor, chief assistant to the late Mr. James Simpson, who has given us, in Appendix B C., the result of inquiries made as to the effects of the drought in several towns.

60. In Manchester it appears that after official notices had been published cautioning the inhabitants against waste, and urging them to economize their supplies, the corporation, on the 3rd of August, limited the supply to the city to 12 hours of the day, stopped the street watering, and diminished the trade supplies by one half. They also made an arrangement with the millowners for reducing by one half the quantity given to the mills on the line of the river, and made compensation in money for the deficiency. In the middle of September the general supply to the town was further limited to eight hours per day, and the quantity for trades also diminished. Many persons were prosecuted for waste or undue use of water. The eight hours' supply lasted seven days, and the 12 hours' supply 76 days.

The following are extracts from Mr. Bateman's evidence in regard to this case:—

With regard to the quantity of water supplied to Manchester during the drought of 1868, you stated that the balance left in store on the 25th of September, after 150 days drought, was 435,000,000 gallons, but that during 45 days there was a diminished quantity supplied to the mills, and further that during 52 days the water was shut off at night. Supposing the supplies to the mills and to the town to have been continued to their full amount during this period, have you calculated what would have been the quantity in store?—We should have exhausted our store, and we should have been, perhaps, something like 200,000,000 or 300,000,000 gallons deficient. 7427.

You are preparing larger storage, are you not?—Yes. Our works are now very far from being complete, but we are constructing two new large reservoirs; and we have a third reservoir which we have never been able to fill owing to the bad foundation, which, as soon as the two others are completed, we shall restore, and that will nearly double our storage at once. It is a mere question of storage in Manchester. We have abundance of water, but we are two years behindhand in our works, and we are two years beforehand in the calculated supply. We have been extending the supplies to the outlying districts so much that, while we have been falling behind in our engineering operations, we have been going too fast in the supply of water to the district, and therefore the two causes together put us into this position this year. 7428.

In our Manchester Waterworks we are at present incomplete. We are behindhand in several of our reservoirs which we are now constructing, and we are beforehand with the quantity of water which we are supplying, so that we are not quite equal to what we should be in storage, and therefore we were not able to give the full supply of water which we could have desired during the last drought. Our available storage in Manchester is equal at present to only 24,000 cubic feet of water per acre of collecting ground. In Liverpool the storage is equal to 48,500; in Dublin it is equal to 25,500; at Loch Katrine it is equal to 30,000; and at Gorbals it is equal to 52,000.

At Rochdale, as early as the 25th June, the supply was limited to four hours per day for 15 weeks; but with this precaution, during the second week in October the store became entirely exhausted, and the town would have been almost without water but that recourse was had to pumping from a colliery in the neighbourhood.

At Bury the store ran so low towards the end of August that it was reserved entirely for compensation to the mills, and the company obtained a supply of seven gallons per head from neighbouring works; for baths and for the numerous manufacturing and trade uses in the town there was none. This continued for five weeks.

At Preston the reservoir became practically dry at the end of August, and costly pumping works were hastily established, which were required for 58 days.

At Kendal the reservoirs were exhausted earlier, and measures of the same kind were adopted.

At Newcastle the gravitation works would have failed for many weeks had they not been supplemented by the pumping from the Tyne.

At Bradford 60,000 of the inhabitants were limited to one day's supply per week for 16 weeks, and 90,000 had their supply gradually reduced during five or six weeks to six hours per day. The want of water for manufactures was here seriously felt.

At Halifax the reduction began on the 11th of May; the domestic supply was limited to 14 hours per day for 66 days, to 10 hours for 10 days, and to six hours per day for 86 days; the supply to large consumers being gradually reduced from 30,000 to 1,000 gallons per day.

At Sheffield the supplies were first reduced in June, and further in July, August, and September, the last reduction being to four hours per day.

The towns of Stockport, Bolton, Ashton, Stalybridge, Oldham, Dewsbury, Warrington, Blackburn, and others suffered more or less, and Mr. Taylor concludes his report with the following remark:—

> The general result has been that nearly all gravitation supplies of water, obtained from drainage grounds, have failed in a manner hitherto unprecedented within the known experience of such works, proving that the data on which they have been based have been fallacious, and that the storage reservoirs and gathering grounds of such works must be greatly increased to meet the demands of years like the present.

61. The causes of this difficulty may lie either in an over-estimate of the available rainfall or in an insufficient provision of storage. The sufficiency of water-collecting plans in these respects must be tested both by the concurrence of several consecutive dry years and by occasional droughts of long duration; and to obtain the necessary data on these points, for any particular district, must require special observations on that district extended over a considerable time.

62. In so variable a climate, and with a rainfall in different parts of the kingdom ranging in round numbers from 20 to 100 inches, it is of primary importance to have the most complete information as to the rainfall, and, as the annual variation is also great, the average fall for a term of years cannot be determined without observations extended over a long period. Less than 20 years would probably not suffice. But the question, with reference to a water supply, has to deal not with the average rainfall of a long term of years, but with a short term depending on the capacity of the storage. In no case yet contemplated would it be prudent to rely on more than the average of three years, and under certain conditions it is doubtful whether two years would not be a safer term.

The Rev. W. Jenyns, in his "Observations on Meteorology," gives an instance in which, even with a term of 10 years, the average varied 7½ inches, the mean quantity in one case being 18½ and in the other 26 inches. In two other terms of 10 years the difference was 2·331 inches.

The experience, however, of half a century would seem necessary to determine the minimum fall for a short term of years. We may take the annual rainfall recorded at the Greenwich Observatory from 1815 to 1868, to average 24 inches. From these observations it appears that during this period of 54 years there were three years in which the rainfall was under 17 inches, or only about two-thirds of the average, viz., in 1832, 1840, and 1864; that during the same period there was one term, and one term only, of three years, 1832–4, in which the average amount of rainfall was a quarter short of the average annual fall; that there were four terms of that length in which the annual rainfall was from a quarter to a sixth short; while once in the 54 years there was a term of five years, the rainfall of which averaged nearly a sixth short. These variations are shown in the following table:

Length of Term.		Average annual Rainfall.	Quantity short of general Average of 24 Inches.
		Inches.	
1 year	1832 (doubtful)	16·1	−7·9
	1840	16·6	−7·4
	1864	16·4	−7·6
2 years	1832–3	18·5	−5·5
	1834–5	20·2	−3·8
	1857–8	19·6	−4·4
	1863–4	18·05	−5·95
3 years	1832–4	18·3	−5·2
	1856–8	20·4	−3·5
5 years	1854–8	20·8	−3·2

The short three-years terms occurred at intervals of 22 years; for the short five years the limits of recurrence are not yet reached.

In the mountainous districts of England the irregularity of the rainfall is still greater. Mr. Symons has given evidence showing that in a period of 22 years at Windermere it has reached as high as 116·26, and fallen as low as 47·54 (1861 and 1855), whilst once in that time the mean of three years (1855–57) did not exceed 52·71. The mean of the 22 years was 79·85.

It is evident, therefore, that a very long series of observations is necessary to be made before any authoritative opinion can be expressed, not only as what may be the true average annual rainfall, but what (for this inquiry is still more important) may be the mean of the three driest years, and at what interval they may occur. In the case of a large city like London, when such a source of supply is proposed, an exact determination seems to us imperative. Of course it will be understood that not only should the observations extend over a long term of years, but also that they should be made in many places so as to get at the average rainfall of the district, which Mr. Symons has well shown to have very different values in immediately adjacent places; as it varied in the same year in fourteen areas in the Lake district, from 45 to 100 inches. When the rainfall has been determined with exactness, the proportion which can be delivered in a hard rock district may be estimated with considerable accuracy.

The system of collecting grounds utilizes, no doubt, the rainfall to the greatest extent. But the great disadvantage is, that the springs to fall back upon in time of drought are insignificant in comparison with the great quantities stored in permeable strata; the very circumstance of a large immediate delivery of the rainfall precludes the possibility of that subterranean storage of a large portion of it, which forms so valuable a resource during severe and long-continued droughts.

63. The question of storage room involves complicated considerations, which have been especially dwelt upon by Mr. Hawkesley. On account of the irregularity of the rainfall, particularly in mountainous districts, it is impracticable to construct reservoirs large enough to store the entire quantity received, so that all large floods occurring when the reservoirs are full must pass away and be lost. Hence the available average obtainable from reservoirs must fall much short of that deduced simply from the fall of rain. We cannot here enter further into this question; but the experience we have above mentioned suffices to show the difficulty of making reliable calculations on this head, even when tolerably complete data are at hand.

64. It is worthy of remark that during the exceptionally long drought of 1868 the Thames and the Lee seem not to have been diminished in volume below the ordinary flow of dry years, a result entirely due to the equalizing effect of the great subterranean stores contributing to their flow.

We shall hereafter go more fully into the advantages of these rivers as sources of supply, which cause them to contrast so favourably with gravitation schemes.

PART II.

ON SOURCES OF SUPPLY OTHER THAN THE MOUNTAINOUS DISTRICTS OF ENGLAND AND WALES.

65. Your Majesty's Second Commission commanded us to inquire "whether there are "other districts, in addition to the high districts of England and Wales, from which a good "supply of unpolluted and wholesome water can be obtained."

Several plans or proposals, of various degrees of magnitude, having for their object to supply the metropolis, wholly or partially, from sources of this character, have been mentioned to us by the parties named in the following list. It will be convenient to divide these into classes, as follows:—

Class I.

From the River Thames or its Tributary Streams.

1. Mr. McClean, from the Thames near Henley.
2. Mr. Bailey Denton, from the higher parts of the Thames basin.
3. Mr. Brown, from the same.
4. Mr. Bravender, from the same.

Class II.

From the Lee.

5. Mr. Mylne, from the upper part of the Lee basin.

Class III.

From the Chalk and Oolite Formations in the Basin of the Thames.

6. The Rev. J. C. Clutterbuck, from the chalk and oolitic area of the Thames basin.
7. Mr. Homersham, from wells in the chalk around London.
8. Mr. P. W. Barlow, from certain chalk springs in North Kent.
9. Mr. Meeson, from chalk springs at Grays in Essex.

Class IV.

Miscellaneous.

10. Mr. Thos. Hennell, from the chalk and Bagshot sands of the neighbourhood of Basingstoke and Farnham.
11. Mr. G. W. Ewens, from certain chalk springs near Havant.
12. Mr. Telford McNeil, from the Bagshot Heath district.

A plan proposed by Mr. A. S. Ormsby, to collect water from artificial drainage surfaces, does not appear to come within the scope of our inquiry.

Some of these projects are merely suggestions, and none of them have been prepared with the completeness and detail of the larger plans. It will, therefore, not be necessary to notice them at the same length.

CLASS I.

From the River Thames or its Tributary Streams.

66. Several projectors, considering that the Thames when it reaches Hampton has become polluted by the drainage of the land and towns above, have proposed to take the water at higher points, generally combining with their propositions other suggested arrangements for the improvement of the supply.

Mr. McClean's Plan.

5498 et seq. 67. Mr. McClean, M.P., Civil Engineer, gives a description of a plan which he brought forward in 1849 and 1850, in conjunction with the late Mr. Blackwell, who was for many years engineer of the Kennet and Avon Canal. It is illustrated by a plan and section which are printed in Appendices T (1) and T (2) to our report.

Mr. McClean's proposition is to embank and canalize the Thames above Medmenham (between Henley and Great Marlow), so as to form, in the present channel of the river, a long series of impounding reservoirs, which would be advantageous not only for storing water but also for improving the navigation. He would then take the water from the lowest of these pounds, 105 feet above low water in London, and proposes thus to obtain a supply of 200,000,000 gallons a day.

The drainage area included is 2,500 square miles, and the mean annual rainfall is estimated at 26 inches.

The aqueduct would be a canal 36 miles in length, the last five miles to be covered. It would be 40 feet wide by 12 feet deep, and is intended to deliver the water in London at about the level of the Paddington Canal, or the New River head, from which level Mr. McClean assumes all the low part of London might be supplied by gravitation, that necessary for the higher parts being pumped to elevated reservoirs at Hampstead and Clapham.

Mr. McClean believes that the quality of the water taken at Medmenham would be very satisfactory.

The estimate for the plan when brought forward was 1,500,000*l.*, excluding the pumping parts of the scheme.

Mr. McClean gives further details, and says he has no doubt that by storing the flood waters in the upper reaches of the Thames more water may be obtained than can ever be required; and that by embanking the river in the way he proposes he would increase the quantity by preventing the water going out on the lands and inundating them, whereby a great deal is lost and the quality much deteriorated. 5637. 5718–21.

Mr. Bailey Denton's Plan.

68. Mr. Bailey Denton's plan, which is illustrated by a map, Appendix V., is thus generally described by him :—

"I am prepared to show that the upper streams of the Thames basin, the tributaries of the Thames, are capable of supplying the metropolis if supplemented by storage, and that that storage would partly consist of the water of under-drainage and the water of drainage by arterial improvements from the upper lands which form the margin of the Thames basin. I should state, however, that my proposal is to take from the Thames and its tributaries, at points above which water may be obtained in positive purity by the proper exercise of conservancy, all that may be required for the supply of London, having stored in winter the surplus waters of that period of the year in order to repay the river system in summer what may be required to maintain it at a fixed standard height." 1532.

With respect to the quantity of water available he makes the following remarks :

"To give some proof that there is water sufficient, I would just mention these facts to the Commission. The area of the watershed of the Thames is 3,300,000 acres, the population we may take at 4,500,000, the average rainfall is 26 inches, the minimum is between 19 and 20 inches, and that minimum is disposed of in this way—3 inches support the perennial supply of the river, that is to say, maintain the river in summer at the ordinary height; taking 3 inches from 20 there remains 17, and of that 17 we find by information of various sorts that a very large share runs off to the sea in winter; but, beyond the fact that this accretion occurs when the rivers are full, there is another fact, that whatever water is taken by under-drainage from the atmosphere it is so much positive increase to the river supply, and as under-drainage proceeds so will the supply be increased." 1547

"I propose to collect the water from the higher portions of the basin, that is, from the oolitic sources on the north of the Thames, say from Cricklade to Oxford, and from the various streams rising in the chalk throughout the whole of the area of 3,300,000 acres. It is not possible to state the quantity of water discharged by springs from the water-bearing strata of the Thames basin, but it is pretty accurately known that, while 1½ inches of rain maintains the ordinary summer flow in the river from April to September inclusive, at least 4 inches runs off during the remaining six months from October to March inclusive, without taking into consideration excessive floods. The ordinary winter flow, in fact, compared with the ordinary summer flow is as 2½ to 1. No dogmas as to loss by evaporation and other causes touch this fact, which manifestly proves, when the discharge drainage water is taken into account, the capability of storing in winter all that can possibly be required for compensation in summer." 1557.

"My proposal embraces three sources of supply with a means of future augmentation, viz., the upper sources of the Thames giving 100,000,000 daily, the Lee giving 60,000,000, the Wey and the Mole giving 40,000,000, making 200,000,000 daily, exclusive of the Colne and the Wandle, which with storage may provide a share at some future time." 1651.

"I have already observed that there is almost a total absence of any reliable gauging of the Thames and its tributaries, but we do know this from the evidence of Mr. Stacey before the Rivers Commission, and a remarkable fact it is, that the general summer average volume at Wolvercot, which is just above Oxford, is 73,000,000 gallons *per diem;* but in the dry summer, 1865, it was reduced to 62,000,000 gallons. But the winter flow is represented by very different figures. On the 2nd of January 1863 the quantity flowing down was 321,000,000 gallons, which is represented as the ordinary winter flow; it increased gradually in five days to 350,000,000, 430,000,000, 588,000,000, 636,000,000, 702,000,000, and 742,000,000, which was the highest it arrived at. I submit that that must go some way to prove the capacity of the Thames basin to supply water if the surplus be stored in winter, to compensate the rivers for what may be taken out of them in summer. It will be observed that Mr. Stacey represents the ordinary winter flow at Wolvercot as about 4½ the ordinary summer flow, instead of 2½ times as I prefer to take it." 1662.

At Lechlade the Thames and Severn Canal joins the Thames, and higher up the North Wiltshire Canal joins the Thames and Severn Canal. Mr. Denton proposes to purchase those canals and utilize them for the collection of the waters of the Thames above, and then to bring the water from Lechlade to London by a conduit, 127 miles in length. This conduit would collect the waters from the various tributaries, the Coln, the Leash, the Windrush, the Evenlode, the Cherwell, and the Ray, into a concentrating reservoir just below Oxford; then, passing down from Oxford to London, the Ock would be in the same way brought under contribution, as well as the Thame, the Loddon, and the Hertfordshire Coln. The main conduit would start from Lechlade at a height of about 220 feet above ordnance datum, and would bring the water to Hampton, where Mr. Denton proposes to deliver it to the present water companies, for them to raise to high-service reservoirs for distribution by gravitation.

He proposes to have compensating reservoirs on the impervious bed of the Oxford clay.

The Wey and the Mole would have a separate system, and be added, when the demand increased. The water from the upper portions of each stream would be brought down by a channel above the surface of the ground of the main valley, so that no flood water or polluted water could enter.

1603. He proposes to intercept the sewage in two ways; for a certain distance up each contributing stream it would be by open drains, but above that (and in fact wherever it would be more economical), there should be compulsory power to raise and apply it to the hills, so as to favour a complete absorption of the sewage into the soil. Mr. Denton says—

1620. "Such a plan must be preferable to irrigation on low meadow ground, where the effluent water, passing *over* instead of *through* soil, must always be charged with a certain proportion of sewage in solution, if not also in suspension. A study of the geological character of the upper portions of the Thames basin—the chalk and the oolite—will satisfy you that, maintaining as they do the river system of the Thames, they are capable of absorbing sewage to any amount, with benefit rather than injury to the springs themselves."

The cost of the works is estimated by Mr. Denton at about 5,320,000*l.*

He does not propose that the cost of the interception of the sewage should form any part of his scheme, as in two years the towns will be bound to carry it out themselves.

6838 et seq. 69. *Mr. T. C. Brown* of Cirencester has given valuable data as to the rainfall in the upper part of the basin of the Thames, from 1845 to 1868; it varied from 19·9 inches in 1854 to 48·8 inches in 1852, and the mean of the 23 years gave 30 inches. He gives information as to the sources of water in the Upper Thames district, and suggests that London might be supplied with pure water, for drinking purposes only, to the extent of say six to nine millions of gallons per day from these sources, conveying it to London by pipes along the Great Western Railway.

App. H. 6888 et seq. 70. *Mr. Bravender*, land agent and surveyor at Cirencester, who has also devoted careful attention for a long period to the upper part of the basin of the Thames, gives important geological and hydrological information on the subject, which will be found in his evidence and in Appendix H.

Regarding the springs in the oolites, we may make the following extracts:—

6906. What is the sum total of those various springs which you have described; you have described Boxwell spring which gives a yield of above 1,000,000 gallons a day, and you say that the pump at the Thames head delivers 3,000,000 gallons a day; can you enumerate the other springs?—There is a spring at Ewen which gives the same as Boxwell spring, or a little more than 1,000,000 gallons. There is Ampney spring at Ampney Crucis, two miles east of Cirencester, which is thrown out from the fuller's earth by a fault, and which gives out an enormous quantity. I find in April /66 I measured the entire flow near the mill and found it to be considerably more than 20,000,000 gallons in the day; and yesterday I visited this spring and carefully measured the flow of water, and find that upwards of 30,000,000 gallons were passing the bridge near the mill. I also visited Bibury spring and found it discharging rather more than the one at Ampney Crucis. There is a spring about a mile above that at Ablington which I have also gauged, and that gives out quite enough to turn a mill; the discharge is more than 2,000,000 gallons. Then there is a spring above Winson from the same source which gives out about a million and a half. The Bibury, Ablington, and Winson springs are on the Coln, the Ampney spring is between the Churn and the Coln, the Ewen spring falls into the Thames at Ashton Keynes and does not get into the Churn.

6907. What are the limits of height above the sea within which those springs occur?—They are all about the same level as Cirencester, or a little higher, from 300 to 380 feet above the sea.

He proposes to add about one-third to the present supply of the water companies, by collecting water in the valleys of the Churn, the Coln (Gloucestershire), the Windrush, and the Ock, and conveying it by a conduit or pipes to London.

Mr. Bravender estimates that about 9 to 11 inches of the mean annual rainfall is available over the whole district.

CLASS II.

From the Lee.

71. The possibility of increasing the supply from the basin of the River Lee, by storage reservoirs or otherwise, has been alluded to by several witnesses, but the only definite plan laid before us for this purpose is the following:—

Mr. Mylne's Plan.

72. Mr. R. W. Mylne, son and formerly assistant of the late Mr. Mylne, who was for 50 years engineer of the New River, has proposed a plan for increasing the supply of water from the basin of the River Lee, which is described at great length in his evidence, and is illustrated by the map, Appendix Z. 4972 et seq.

He proposes to make the drainage area better available by collecting the streams and chalk springs into impounding reservoirs to be formed at various places, but principally at Enfield Chase, which, being on the London clay, is, he conceives, more favourable for the purpose than any sites that can be found on the Lee proper.

This plan would, he states, bring 70,000,000 gallons daily into London, in substitution for the present supplies of the New River and East London companies, adding therefore about 28,000,000 gallons. This would be, he says, a minimum on the driest years.

The cost of these works, excluding compensation, is estimated by Mr. Mylne at 1,250,000*l.*

The following extracts from Mr. Mylne's evidence will illustrate the nature of his plan:—

"In contradistinction to the view recently put forward, that no means of storage could profitably be carried out without descending as low in the valley as Broxbourn or Waltham, it is herein suggested that a considerable quantity from the upper tributaries mostly of pure spring water might be diverted and transferred by gravitation from a point above Hertford direct to convenient sites for reservoirs at Enfield Chase on the London clay beyond and altogether outside of the watershed of the upper portion of the Lee basin, and a further quantity might be impounded within the basin in the valley of the Rib. It is proposed to make diversion cuts on the before-named four tributaries, viz., the Lee proper, the Mimram, the Beane, and the Rib, and convey the collected quantities along an artificial channel to a point in the valley 2½ miles above Hertford; the total contributing area would be 246 square miles, giving an average daily yield of 43,000,000 gallons, but it is only proposed to take 40,000,000 gallons, and to convey that volume in a direct line to London through a tunnel and covered channel 5½ miles in length into reservoirs proposed to be made on Enfield Chase. The two proposed reservoirs to be made, into which the waters would gravitate, will cover an area of 270 acres, and will contain, including the tunnel, 1,391,000,000 gallons with a top-water level of 130 feet above Trinity high-water mark and a maximum depth of 37 feet of water. . . . . In order to increase the extent of reservoirs on Enfield Chase, and to bring a higher water level into use for distribution, it is proposed to construct four further reservoirs at the additional height of 36 feet, and to lift into them by steam power a considerable portion of the collectable quantity entering into the two gravitation reservoirs previously described. These will cover an area of 340 acres and will contain 1,249,000,000 gallons, with a top-water level of 166 feet and a maximum depth of about 38 feet of water. The total storage capacity of the six reservoirs on Enfield Chase would therefore amount to 2,640,000,000 gallons or 423,552,000 cubic feet. The execution of the tunnelled part would be throughout its length entirely in chalk and being near to the upper surface of the chalk and overlaid with tertiary sands and intersecting the local disturbance already alluded to, as well as across the general dip of the chalk, no doubt a considerable quantity of water may be expected. It is assumed that from the tunnel works, with the additional seven square miles of gathering ground at its southern end, together with the Lee tributaries, it will secure a total daily yield of at least 47,000,000 gallons. The storage capacity necessary for securing a uniform daily flow has been ascertained at Feilde's weir to be for 118 days 66,000,000 gallons a day, and inasmuch as the volume is proportionably much larger and more constant from the upper tributaries, it is estimated that a provision of 90 days' storage would be quite sufficient for the intended gathering ground. On the Rib it is proposed to adopt the plans designed by the late Mr. Rendel for the reservoir below Standon, which exceeds 200 acres, and would hold above 500,000,000 gallons, with a maximum depth of 20 feet of water. . . . . Besides the works contemplated for the diversion of the upper tributaries of the Lee, it is intended to retain the New River channel for the flow of the Chadwell spring, and to collect all the springs issuing from the west bank of the valley between Amwell and Rye House, and lift them by steam power about 10 to 15 feet into the New River; also to purchase the water rights of the copious springs which now work Hoddesdon Mill and to collect those and others in the locality, and lift them also from 15 to 20 feet into the New River. Those sources, it has already been stated, may be calculated upon to yield the respective quantities of 4,500,000, 6,000,000 and 8,000,000 gallons per day, and out of the gravels and sands near Hoddesdon, where the water is assumed to absorb and soak away into the sands under the London clay, a quantity of at least 4,500,000 may be estimated, and could be lifted into the New River at a height of not more than 20 feet. A very much larger quantity from this source might possibly be obtained, but perhaps only effectively by longitudinal adits or driftways up the sides of the valley, works which are not contemplated in the present scheme. The collective quantity of all these strictly spring waters could be secured at a very small cost, and would amount in quantity in dry seasons to about 23,000,000 gallons per 4995

day, a volume equal to the present flow in the New River, and therefore, notwithstanding the proposed abandonment of all further abstraction of water out of the Lee at Ware, the New River would remain in its present condition as to volume as far down as Enfield, where further works are suggested. . . . . With regard to the manner of distributing the total daily yield of 47,000,000 from the store reservoirs and 23,000,000 gallons from the New River, in all 70,000,000, there are various modes of division that might be made, but considering that two companies have to be provided for, it is suggested that the East London Company should have 30,000,000 delivered over 24 hours, from filter-beds placed at the foot of the high-level reservoirs, and pipes from thence to Stamford Hill, delivering at the level of 112 feet into a service reservoir. The East London Company have a small reservoir at Stamford Hill, and I propose by means of a large main to deliver there at the level of 112 feet, and from thence the distribution over the whole of the East London district would be by gravitation, except perhaps a small area immediately in the vicinity of Stamford Hill itself."

5000. "The advantages to the East London Company are, that the water would be drawn from a purer source than at their present intake, being freed from the valley drainage and future cost of diverting it, and obtaining a gravitation supply in lieu of pumping, and the New River Company would have an increase and improved supply, freeing them from the necessity for many years to come of looking to the river Thames or other distant sources, but confining their endeavours to within the legitimate and as yet unutilized valley waters of the river Lee."

5024. "That would be 63 days' storage on Enfield Chase, with a further storage on the river Rib."

CLASS III.

From the Chalk Formations in the Basin of the Thames.

73. Many witnesses have alluded to the great natural storage of water in the porous strata, chiefly the chalk, which form so large a portion of the drainage area of the Thames basin. By reference to the geological map (Appendix Y.), and to the evidence of

3041. Mr. J. T. Harrison, it will be seen that out of 3,676 square miles of surface no less than 1,047, or two-sevenths of the whole, consist of the chalk downs so well known, and extending so widely over this part of England. These strata absorb and store a large portion of the rainfall; and although much of this store finds its way by springs into the streams, and so already contributes to the supplies drawn from them, there has always been a desire on the part of those interested in water collection to go in preference directly to the stores themselves.

The water in the chalk round London has repeatedly been proposed as a source of supply, either wholly or partially, for the metropolis. The New River was constructed to take advantage of chalk springs, and a large portion of the water it at present conveys comes from this source.

It is on record that in 1827, Martin, the artist, proposed to bring the water of the Colne (the principal chalk river to the north of London) to the metropolis, and Mr. Telford, in 1834, proposed to supply London from the Verulam and the Wandle, both effluents directly from the chalk. A few years later, in 1840, a company was started called the London and Westminster Water Company, who chose Watford as their source, backed by a strong approving report from the late Robert Stephenson; and some years later this was revived under the name of the London (Watford) Spring Water Company.

The Chemical Commission of 1851 devoted considerable attention to the examination of the chalk water, and recommended it strongly as the best supply for the metropolis, on the ground that the quantity was large, and the quality superior to that of any other water that could be obtained. The following extracts from their Report will illustrate their views on the subject:—

"The water which it is proposed to bring from the neighbourhood of Watford, for the supply of the metropolis, claims consideration as being entirely spring water, and has a peculiar scientific interest as representing the pure primitive basis of the river water which is at present consumed. A supply of water of the same description is also offered from the south side of the river, to be derived from the chalk strata upon the line of the South-eastern Railway, and the quantity attainable on either side is said to be so considerable as to exceed the actual requirements of the metropolis. Of the chalk district, which surrounds London on all sides, and covers an area of not less than 3,000 square miles, the upper strata appear to be charged with water to a height of several hundred feet above the level of the sea. This water issues again in numerous natural springs, or may be reached by moderate boring. The daily yield of single springs or of artificial wells in some parts of this district is remarkable for its quantity, often amounting to 300,000 gallons, and occasionally rising to 1,000,000 gallons and upwards; a copiousness of flow, which is referred to the chalk rock being highly pervious to water, from its fractured and cavernous state. This chalk spring water is not to be confounded with the water of the deep wells of London, although the latter are carried into the chalk strata below the clay, but differs as completely in composition from the latter as any two waters can well do. Nor does any evidence exist of a relation or dependence of the London deep wells upon the water of the chalk districts; nor reason to infer that the yield of the latter would be restricted within the narrow limits of the former. Indeed, all grounds for comparison of the two waters will disappear if it is true, as many well-informed persons believe, that the

deep wells of London draw their supplies chiefly from the sands under the blue clay and above the chalk, the water of which sands appears to flood the upper beds of the chalk. The superposition of the thick mass of strata which form the London clay, certainly alters considerably the condition of the chalk below it, and renders it no longer comparable with the water-bearing strata of chalk in Hertfordshire and Kent, which are not so covered, and are situated above the level of the sea. The whole original supply of the New River Company, from the Chadwell and Amwell springs, was water of the kind under consideration, and a very sensible proportion of the present large supply of that company is still spring or well water of the same nature."

"On comparing the Watford spring water with the New River water and Thames water as supplied by the water companies, a considerable similarity is observed in the character of their saline constituents. The lime is in larger quantity in the spring water, but then it is nearly if not entirely in the state of carbonate. The earthy sulphates, which give rise to permanent hardness, are almost entirely absent from the spring water. The general character of this supply may be further described as follows:—

"1. The spring water contains no matter in suspension to cause turbidity or colour; its clearness and brilliancy are unexceptionable.

"2. It possesses a desirable coolness, having at all seasons a temperature between 50° and 52°.

"3. The amount of organic matter it contains is inconsiderable, and of a kind which appears to be incapable of undergoing putrefactive decomposition, so that it may be safely disregarded.

"4. The salts which it contains would not interfere with its use as a beverage. It is indeed a choice water for drinking."

We have received the four following propositions for utilizing this source.

74. The *Rev. J. C. Clutterbuck*, who has paid much attention to this subject, gives his views upon it at considerable length. 1782 et seq.

He believes that considering the large chalk springs issuing at high levels in various places round London, it would be possible to find in such springs a considerable quantity of water, of good quality. The most reliable sources are springs in the chalk, and speaking of their abundance he says:—

"Along all valleys in which rivers run, the Kennet, for instance, the chalk streams are fed from their sources down to the place where they deliver themselves into the river, because they run just on the springs, and are fed as they go. You may not see very large springs, but you will see an immense gathering of water in the course of the river by the discharge of the water from the springs." 1836.

He disapproves, however, of obtaining the water from the chalk by pumping, in regard to which he says:—

"You would obtain a certain quantity, but it would be at the expense of the rivers; the rivers would cease to flow. When my advice has been asked I have invariably said, Take the water as it flows above ground, and do not tamper with it below; that is what I have invariably said, and I believe it is sound advice." 1837.

By taking the water as it flows down the rivers, and by an arrangement of reservoirs, he considers there might be an immense storage of water in the upper districts.

The springs in the chalk under London have, he considers, been over-taxed, and the consequence has been an unnatural depression of the water. Any hope of obtaining a supply for the metropolis from this source would in his opinion be a failure.

75. *Mr. Homersham*, civil engineer, who has supplied Caterham and other districts with water drawn from the chalk areas round London, proposes to supply the metropolis entirely with spring water from the chalk, and to do away with the present supply taken from the Thames. He believes that there would be no difficulty in getting from this source a very large quantity. The cost would be small, by reason of the readiness and cheapness with which water can be obtained from the chalk in well-selected situations. He considers that any objection to the hardness of chalk water may be obviated by the use of Dr. Clark's softening process, in which he has had considerable experience. 6762 et seq.

The water at Caterham appears by Dr. Frankland's analysis to be remarkably free from organic matter. App. AX (2.)

76. *Mr. P. W. Barlow*, civil engineer, believes that the ultimate solution of the difficulty of supplying London will be found in the chalk. He has found several powerful springs issuing from the chalk on the south side of the Thames; in one small district near Gravesend they amount to 10,000,000 gallons per day. He believes that by driving a tunnel parallel with the river, 20 miles long, from Lewisham to Gravesend, or a little beyond, 60,000,000 gallons per day might be obtained. 5959 et seq.

77. *Mr. R. Meeson* has given us an account of large springs issuing from the chalk pits at Grays, in Essex, and which furnish an abundant supply. The water is of good quality, limpid and of uniform temperature, very similar to that of the Amwell springs, but rather harder, being 16·6° of Clark's test. About 450,000 gallons per day are at present used to supply Brentwood and Romford and parts adjacent. About 6863 et seq.

7,000,000 gallons per day have, however, been raised, and Mr. Meeson believes the springs would supply 10,000,000 at least.

We add some extracts from Mr. Meeson's evidence:—

"The water springs are situate in the chalk pits at Grays in Essex, about a mile distant from the Thames. When undisturbed they rise to a height varying from about four feet to eight feet below Trinity high-water mark. . . . . The depth of water which passed over the gauge, which was 3 feet 8 inches wide there, was $5\frac{1}{4}$ inches, so that the quantity then obtained every 24 hours exceeded 2,100,000 gallons, besides that used on the works. This quantity was delivered daily, the engines being worked day and night, ceasing for only a few hours between Saturday evening and Sunday morning. During the week the water was lowered about 12 feet, and it then became possible to excavate the chalk to that additional depth over a small space; but when the engines ceased working the water speedily rose to its former height, and it occupied an entire day and night so to reduce the water as that work might be resumed; and throughout the entire remainder of the week the springs yielded the supply I have mentioned, which was all that the pumps then in use were capable of delivering. . . . . These operations have been carried on now for many years, yet notwithstanding so large a quantity has been pumped daily into the Thames, no perceptible alteration has taken place in either the quantity or quality of the water."

CLASS IV.

Miscellaneous Schemes.

Mr. Hennell's Plan.

1913 et seq. 78. Mr. Thomas Hennell proposes to bring 14,000,000 gallons of water per day to London, in extension of the present supply, from the Basingstoke Canal, and from sources adjacent to it, aided by storage reservoirs to hold 840 millions of gallons. He would purchase the canal from the company and use it as a conduit, forming a paved brick channel throughout its length.

He calculates that six-sevenths of the water would come from the chalk at the Basingstoke end of the canal, where it is 252 feet above ordnance datum, and the remainder from the district of the Bagshot sands between Farnborough and Woking. The quantity might, however, be largely increased.

In answer to questions respecting the springs intersected by the canal in passing through the chalk below Basingstoke, Mr. Hennell states:

2013. "To take first the Whitewater; that I found in October contained, in round numbers, 10,500,000 gallons. I propose to take one-third of that, and that is rather the largest of the three principal sources."

2014. "I measured the stream again last week, and I found 14,500,000 gallons daily. Then, in addition to that, there are the Mapledurwell and the Newram springs within a mile of Basingstoke."

2015. "The Mapledurwell springs contain 1,980,000 gallons. There are springs east and west of the village; those which are on the east side of the village I cannot conveniently take, because they are at a low level, but they unite afterwards, and therefore I take two-thirds of the western springs only, which would be equal to one-third of the whole. They unite before they come into any stream where they would be required, and therefore I take two-thirds of 1,980,000, that is 1,320,000. Then the Newram springs contain, in round numbers, 4,500,000, of which I take two-thirds; that is 3,000,000."

2016. "The entire total is 28,296,000."

The water would be conveyed by the canal to a point near Weybridge, from whence a conduit eight miles long would have to be made to Thames Ditton, where the water would be received by the companies and pumped for the supply of the town.

The estimated cost, including the purchase of the canal, is set down by Mr. Hennell at 280,000*l.*

Mr. Ewens' Plan.

3685 et seq. 79. Mr. G. W. Ewens points out the existence of certain springs in the chalk from Emsworth to Bedhampton near Chichester, from which he believes a large quantity of pure water might be obtained of a quality very similar to New River water. He mentions springs of this kind at Emsworth, Havant, Bedhampton, Brockhampton, and Langbourne, and adds:

3699. "There are six streams formed by nine separate series of springs; each of these streams flow into the sea at an average distance of half a mile from the spot from whence they take their rise. There are eight flour mills driven by these six streams."

The water might be pumped into large reservoirs on Portsdown Hill and near Petersfield, and conveyed by a conduit to London.

Mr. Telford McNeil's Plan.

5815 et seq. 80. Mr. Telford McNeil proposes to give a supply of 200,000,000 gallons daily by intercepting water from the Thames at Teddington, raising it 200 to 380 feet, and conveying it in an open channel to the Bagshot sands, through which it is to be made to filter, and from which it is to be conveyed back in a closed conduit to London, and

again pumped into reservoirs at Norwood and Hampstead. The estimate is something above 6,000,000*l.*

Remarks on the above-mentioned Plans.

81. The chief feature of Mr. McClean's plan is the mode by which he proposes to effect the storage in the Thames, and this may deserve consideration whenever it may be found necessary largely to increase the quantity of water drawn from the river. The plan for taking the water from Medmenham would be very expensive, and, probably, of doubtful utility as regards quality (for reasons that will hereafter be shown), while it would be open to the objection of depriving the 37 miles of river between Medmenham and Hampton of a large proportion of its dry weather volume.

The plan of Mr. Bailey Denton, a gentleman of very large experience in drainage matters, is remarkable on account of the manner in which he proposes to deal with the sewage. His opinions also as to the mode of increased storage are valuable.

Mr. Brown and Mr. Bravender point to the value of the springs in the oolites as subsidiary sources of supply.

The plan of Mr. Mylne for increasing the supply from the Lee presents some ingenious and novel features. By the proposed mode of collection he would obtain the water in a state of greater purity than at present, while the mode of storage also claims advantages over former plans. We question whether the quantity Mr. Mylne estimates could be rendered available in the driest seasons, but if any measures should be considered desirable for enlarging and improving the supply from the Lee, his plan would deserve consideration.

With respect to the water sources in the chalk formations we shall speak more at length hereafter. Mr. Meeson's springs at Grays deserve special mention on account of the practical use already made of them by him.

Mr. Hennell's plan has some novelty, but the water might probably be more advantageously utilized for other towns nearer the line of canal.

Mr. Ewens calls attention to some fine springs; they are too far away to be of use for London, but might probably be of value to towns in the neighbourhood.

GENERAL REMARKS ON THE SOURCES AND SPRINGS IN THE THAMES BASIN.

82. It may now be well to review all the resources of the Thames basin before we proceed to consider the important question of the future supply of the metropolis.

83. In order to explain the geological and physical features of this tract of country we have had prepared the large map of the Thames basin marked Appendix Y (1). It is drawn on the scale of six miles to an inch; it shows by colours the various geological formations; and it has contour lines marked upon it at every 100 feet difference of altitude, by which the levels of the ground at the various parts of the basin may be seen. Another corresponding map, Appendix Y (2), has the contours shaded, by which the varying elevations of the ground are made more distinct.

84. The drainage of the Thames valley above Kingston extends over 3,676 square miles; this area receives an average annual rainfall of about 27·2 inches, and one-third of the quantity due to this rainfall flows down the Thames at Hampton.

This delivery is the result of very complex conditions. One third of the area consists of impermeable clays, and two-thirds (or about 2,450 square miles) of permeable oolitic limestones, sands, and chalk. From the former, the rainfall, after allowing for evaporation and for vegetation, flows off at once, and whenever in excess gives rise to floods, whereas the rainfall on the latter is at once stored up, and its ultimate delivery through springs to the streams and rivers is spread over weeks or months. To this cause is owing the permanence of flow of a river draining a permeable rock district, compared with the irregular delivery of a river draining an impermeable district, and it is a consideration of great importance in a question of water supply.

85. In order to indicate the extent of the underground reservoirs formed by the permeable strata, and the sources on which the springs depend for their supplies, we have constructed a series of sections, shown in Appendix Y (3). A complete and elaborate survey would be necessary in order to give the exact lines, whether of the surface of the ground or of the levels of the underground water, but these sections will serve to give an

idea, sufficiently approximate for our object, of the extent and capacity of the underground reservoirs on which the streams depend for their supplies during periods of drought.

86. All permeable formations tend necessarily, by the absorption of rain, to become charged with water up to the level generally of the streams and rivers of the district; and further, owing to the resistance experienced by the rain water in passing through the strata, the water, wherever the ground rises above the level of the rivers, accumulates therein in proportion to the length, breadth, and height of the range of hills, so that instead of the line of underground water level presenting a flat surface between two valleys, it presents a curved surface varying according to certain conditions. Taking the lowest point of escape as determining the permanent level above which all the water tends to run off in springs, the height of the curve above this level gives the head of water on which the springs depend for their supply. The rise of the water being from the circumference of the hills to the centre, the underground reservoirs form more or less dome-shaped masses, the surface of which is constantly fluctuating in proportion to the difference between the amount of rain percolating through the strata and the quantity of water which escapes by the springs.

In the district we have to deal with, the crown of the curve often rises 50 to 200 feet or more above the permanent spring levels, while the actual height of the curve is known to vary in accordance with the variation in the rainfall, in many cases as much as 50 to 80 feet or more. Where the conditions are favourable to a large underground reservoir the springs hardly ever run dry. Mr. Beardmore, as the result of many years' observations in the chalk district of the Lee, sees reason to believe that the storing power of the chalk hills there holds out at least 16 months.

The darker water lines in the sections represent the upper portion of the head of water accumulating in the hills, and serving to feed the higher and smaller springs; the next shade shows the larger portion which goes to feed the lower and more perennial springs. The portion of the sections over which the faint water lines extend represents theoretically those portions of the permeable strata which are permanently charged with water, and from which wells can always draw a supply—in sand strata at once, and in the more compact limestones and in chalk as soon as any of the intercommunicating fissures or crevices are reached, unless any excessive exhaustion has produced a local depression of the water level.

Further, some of the water below the lines of permanent level inland has a slow underground movement to still lower levels, unless intercepted or thrown out by faults in the strata or by some other cause. This underground drainage is not, however, coincident with the surface drainage; and while some of the water-bearing strata of the Thames basin are not available as underground sources of supply by means of wells at or near London, other strata, on the contrary, out of the London basin, are so available from the circumstance of the dip of the beds being towards London. The extent of this underground area supposed to centre towards London is represented by dotted lines on the map, Appendix Y (1).

Where the permeable strata only cap the hills the springs issue of course on the sides of the valleys at the junction of the impermeable strata.

87. In the order of superposition the highest permeable strata near London, excluding the superficial beds of gravel, are—

The *Bagshot Sands*, which are from 100 to 350 feet thick and extend over an area of 211 square miles. As these strata consist almost entirely of loose quartzose sands, the underground water oozes out commonly at their junction with the London clay, and is rarely conducted into any particular channel of escape so as to form springs, and the loss by evaporation is large. There are in fact throughout this area no springs of any importance; only a few small tributaries of the Thames and the Wey have their sources in this district, and the supply to the wells is not large. The water generally is soft and pure, but in some places it is ferruginous. We cannot look to these sands for any additional water supply, (although they attracted a good deal of attention a few years since,) for the whole of the water now delivered by them passes into the Thames or the Wey. None passes elsewhere underground.

The *London Clay* underlies the Bagshot sands and forms a great impermeable bed from 400 to 450 feet thick.

Lower Tertiary Sands.—These beds, which are only from 50 to 100 feet thick, are of no importance so far as springs are concerned at their outcrop, but they have been useful sources of supply to some of the deep wells under London. Owing, however, to the great increase in the number of these wells, and the fall in the level of the water, the

underlying chalk is now generally resorted to as the better source of supply. In many places round London where they have not been so drawn upon they still yield a good supply of water.

88. The *Chalk*, from its large area (1,047 square miles above Kingston, but more than double that in the whole basin); from its great thickness—500 to 1,000 feet—and from its peculiar lithological character, forms a very important source of water supply, both by springs and by means of wells. Almost all the rain falling on its surface is absorbed or percolates through the fissured surface. So close is its texture that the bulk of the rain takes weeks and months to filter down to the level of the water line in the interior of the chalk hills—a line the depth of which below the surface of the ground may vary from 100 to 300 feet according to the height of the hills. The water thus stored escapes in several ways—some by the streams rising within the chalk district,—some by springs feeding directly the larger rivers flowing through it,—another portion overflows at the outer escarpment of the chalk,—and a larger portion issues near its junction with the tertiary strata. A certain quantity also passes underground, supplies the wells, in the central tertiary area, and escapes in part at still lower levels at more distant points.

Where the rise of the bottom of the valleys is more rapid than that of the line of water level, the valleys assume the character so common in chalk districts, of dry valleys. Others of these valleys tap the springs in their lower part, whilst the upper part of the same valley is dry. In these cases the head of the stream will often change its position two or three miles higher or lower in the valley, accordingly as the rise and fall of the water level in the hills are influenced by the rainfall. Where the deeper and larger river valleys traverse the chalk area and intersect the line of water level, these valleys become fringed on the river level with a series of springs, as the Thames in its course from Wallingford to Taplow, the Lee above Broxbourne, the Ravensbourne, the Cray, and the Darenth, and the Thames again from Woolwich to Gravesend.

The springs along the line of outcrop of the chalk marl and gault being on a higher level than any others, the head of water supplying them is much smaller than that supplying the springs on lower levels within the chalk area, and consequently with few exceptions these springs are small. They are, however, extremely numerous. Almost every little village under the range of the chalk downs in Wiltshire, Oxfordshire, and further eastward, has its spring near the foot of the chalk hills. These collectively would furnish a considerable quantity of water, but they are too scattered and wide apart to be available for any general purpose. There are, however, a few large springs amongst them. There is one, for example, at Cherhill near Calne. This spring never fails, and is said to yield from two to three million gallons of water daily. It is represented at the end of section No. 4, Appendix Y (3). There are also copious springs near Ellensborough, at Barton-in-the-Clay near Prince's Risborough, near Swindon, and at many places along the foot of the North Downs of Kent and Surrey.

Another and more important class of springs are those which escape along the inner edge of the chalk along or near the line where it passes under the tertiary strata, and again where it approaches the sea level. These springs are all placed on relatively low levels, and derive their supplies from the large head of water which extends in the chalk hills beyond them up to the outcrop of the beds underlying that formation. As the difference of level between these exterior and interior springs varies often from 150 to 300 feet, the latter are necessarily much more powerful and permanent, and will continue to run long after most of the others have become dry. Among the more copious and remarkable springs of this class are those at Chadwell near Ware, Otter's pool near Watford, Froxfield near Hungerford, Beddington and Carshalton, Orpington, Grays Thurrock, Springhead near Gravesend, Ospringe near Faversham, besides a number of smaller ones. The origin and source of supply of some of these springs are indicated in the sections.

In the neighbourhood of London the wells in the chalk form an important auxiliary source of water supply, and they might, no doubt, be considerably increased in Kent without interfering with the springs in the valleys above London, as the store from which those wells draw their supplies overflows in numberless springs along the Thames below London at levels where they are not generally available.

The lower beds of the chalk are so argillaceous as often to hold up the water and to lose their ordinary permeable character.

89. The *Upper Greensand* forms so much a part of the lower chalk, and is so slightly developed near London, that we have grouped it with the chalk. It is only in Wiltshire that it acquires an importance entitling it to be considered apart. Under London it becomes also so argillaceous as to lose its water-bearing character.

The upper and lower Greensands are separated by 100 to 200 feet of impermeable clay, known as the *Gault*. The numerous small streams rising at the foot of the chalk hills have their source generally in springs thrown out by the chalk-marl, or the gault.

The *Lower Greensands* form a mass of siliceous sandy strata from 200 to 500 feet thick, and with an available area of above 500 square miles. Cropping out both to the north and south of London conformably to the chalk, which is known to pass below the tertiary strata under London, it was supposed that the Lower Greensands were also continuous below London, in the same way as the Lower Greensands of the plains of Champagne pass under Paris at the depth of 1,800 feet. The experience, however, obtained at Kentish Town, at the deep well sunk through the chalk a few years since by the Hampstead Company, showed that although the tertiary strata, the chalk, and the gault followed in regular order, a change took place at the base of the gault, and instead of the lower greensands, a series of red and grey sandstones were met with. These were bored into for a thickness of 188 feet without passing through them and the work was abandoned. (Appendix, Y 3, Section No. 2.) No organic remains were discovered to indicate the age of these sandstones, and the hand specimens were insufficient to determine the question. They may have belonged to some member of the New Red Sandstone, or possibly to the Old Red. In any case they seem to form part of an underground ridge of old secondary or palæozoic rocks which, ranging from Belgium, pass under the chalk at Calais and Harwich, at both which places they have been met with, and probably extend under London in the direction of Somersetshire. The width of this belt can only be determined by experiment.

It is known that the Lower Greensands exist at Reigate and are about 450 feet thick, and that they occur again in Bedfordshire with a thickness of about 200 feet. In both cases they dip towards London, disappearing beneath the gault. We know that they do not exist under London (Kentish Town). It follows, therefore, that in the one case they cease at some point between Reigate or Merstham and London, and in the other between Baldock and London. As at both ends they are of considerable thickness, and the gault is continuous, it is certain that the greensands must range from these outcrops some way towards London, probably thinning off gradually against the flanks of the underground ridge of old rocks. So far as they continue, so far will they form a valuable and copious water-bearing bed, the water from which would overflow at the levels lower than that of their outcrop. The extent of their underground range could only be determined by boring. It might be as far as Croydon, or even still nearer to London. The same would happen to the north of London, but the distance there is greater, the beds are not so thick, and the conditions generally are less favourable. The great purity of the water from the Grenelle and other artesian wells in the Lower Greensand is well known, and there is reason to suppose that the quality of the water obtained from the same formation in the vicinity of London would prove equally good. The excessive length of filtration would at all events ensure freedom from organic impurities.

The quality of the water flowing from the Lower Greensands is excellent for all domestic purposes, being bright and limpid, of a degree of hardness varying only from about 3° to 9 of Clark's test, and generally very free from organic matter. A considerable amount of evidence on the quality of this water was collected by the Board of Health in 1850.

The springs in this formation are not very numerous, owing to the prevalence of sandy beds, but in some of the more stony beds there are some fine springs, as for example:—

1. The springs in Bradbourne Park and at Riverhead near Sevenoaks.
2. Several springs near Dorking.
3. Spring at Weston Street.
4. Spring at Moorhead Park near Farnham.

90. To the south of London a great thickness of *Weald clay* separates the Lower Greensand from the *Hastings sand* of the weald of Kent and Sussex; but although these beds are thick they are very local, only partially permeable, and are of no avail.

91. The strata which next succeed are only developed in the north and north-west of the London basin.

The *Portland Stone and Sands* are from 35 to 50 feet thick, and are, in some places, of local importance, but none of the springs would be available for distant purposes.

The *Kimmeridge Clay* is impermeable and from 250 to 300 feet thick.

The *Coral Rag* and *Calcareous Grit* are from 20 to 50 feet thick and give rise but to a few small springs. These beds thin off as they range to the east and south-east, so that in Buckinghamshire and probably underground in Berkshire the Kimmeridge and Oxford clays come into contact, and the coral rag ceases to exist.

The *Oxford clay* is impermeable, and attains in Oxfordshire a thickness of 400 to 500 feet.

92. The *Great Oolite* and subordinate beds may for our purposes be taken together. They form in Oxfordshire an important group of permeable strata 250 to 300 feet thick. They have a collecting area of about 300 square miles, and give rise to a number of fine springs, amongst which those of Ampney, Bibury, Boxwell, and Thames Head have been described by Mr. Bravender and Mr. Brown, and are stated by Mr. Pole to have been yielding at the time of his visit probably not less than 10 million gallons of water daily.

Most of the springs of this series are thrown out by the *Fullers Earth*, an impermeable bed of no great thickness in this district—40 to 60 feet—and persistent only over a limited part of the area. (See section No. 3.)

The *Inferior Oolite* and underlying sands reposing on the lias form another important water-bearing formation. They are from 300 to 320 feet thick, and extend in the Thames basin over about 180 square miles. As the hills of this formation rise 230 to 300 feet above the valleys and have a considerable range, the head of underground water is large and furnishes several important and perennial springs, such as those of Syreford, and the Seven Springs, of which the yield is stated by Mr. Pole to have been at the time of his visit from three to four million gallons of water daily. (See section No. 3.)

These various oolitic strata consist of beds of rubbly limestones, soft freestones, sands and fissile sandstones, through which the water passes chiefly by fissures; and although often traversing a great thickness of strata, it is not filtered to the same extent as it is in the chalk and Lower Greensands.

Mr. Hull has shown* that the inferior oolite and underlying sands, which in the neighbourhood of Cheltenham are about 320 feet thick, thin off as they range eastward, and probably die out about the centre of Oxfordshire. In the same way he shows that the great oolite and accompanying beds, there about 300 feet thick, also thin to the eastward, and they apparently do not extend more than a few miles further east than the inferior oolite.

It follows that the underground passage of water through these oolites, which might, had these formations ranged in full force eastward, have been carried as far as London, the dip being in that direction, is stopped by the thinning out of those beds, and by the closing in, as it were, of the Lias, Oxford clay, and Kimmeridge clay. Although, therefore, the surface drainage of the Cirencester and Bampton districts runs into the Thames valley, the subterranean water channels are intercepted and do not reach London, and the oolitic series must be excluded as a possible source of supply by deep wells in the London district.

93. The exact proportion of the rainfall absorbed by the different permeable and porous strata, and which is given out again in the form of springs, yet has to be determined. It varies according to the lithological character of the water-bearing strata. The general results are, however, known in many cases. Thus the annual flow of the Thames at Hampton and of the Seine at Paris, both draining areas composed partly of permeable and partly of impermeable strata, is equal to about one-third of the rainfall. In a district where the impermeable strata predominate, the total deliveries will be larger, but they will follow close upon the rainfall; whereas, as the permeable strata predominate, so will the rainfall be stored in the hills, and its delivery be spread over a greater length of time. The summer flow in a dry season consists almost entirely of the supplies derived from deep-seated springs. Mr. J. T. Harrison, to whose evidence we would refer for many interesting details on these points, estimates this generally in the Thames district to be equal to one-sixth of the rainfall.

94. The importance of such a condition of things for the supply of this large metropolis cannot be over-estimated. It ensures that permanence and regularity which are necessarily among the most important elements in a metropolitan water supply. With natural subterranean reservoirs extending over above 2,000 square miles, a storage reserve is provided comparatively independent of the seasons, and maintained by the ordinary operations of nature, while no filtration can equal that effected through masses of sand, sandstone, earthy limestones, or chalk, from 50 to 300 feet thick. The quantity of mineral matter taken up is in most cases moderate, while the really objectionable ingredient—the organic matter—is reduced to a minimum. However different the results obtained in

* Quart. Journ. Geol. Soc., vol. xvi. p. 63.

other cases, the two under-mentioned eminent chemists agree in their conclusions on this point, as will be seen by the following table, the quantities having reference in the first case to 100,000 parts, and in the second to a gallon of water:—

	Dr. Frankland.			Prof. Wanklyn.
	Organic Carbon.	Organic Nitrogen.	Nitrogen as Nitrates and Nitrites.	Albuminoid Ammonia (representing the Organic Matter containing Nitrogen).
Caterham well (chalk)	·020	·006	·027	0·000
Spring near Moor Park (lower greensand)	·030	·010	·045	—
Cold Harbour (lower greensand)	—	—	—	0·000
Otter Spring (chalk)	·026	·012	·422	—
Loch Katrine	·256	·008	·031	0·130
Welsh waters	·289	·004	·022	—
Cumberland Lakes	·211	·006	·009	—
Thames water at Hampton	·260	·024	·192	0·134

At the same time the water is kept at a uniform low temperature and protected from light and air, conditions unfavorable to the existence of living organisms. Springs from such sources probably represent potable waters in their best state; and amongst the favourable specimens of such waters may be instanced many chalk springs, the water from the lower chalk at Caterham, and some of the springs of the Lower Greensands of Surrey.

It is satisfactory to know that there exists within easy reach of London a supply of the best and purest spring water which, in case of need, could readily be rendered available as an auxiliary source of water supply for the metropolis, in quantity sufficient at all events for drinking, if not for other purposes.

PART III.

ON THE PRESENT WATER SUPPLY OF THE METROPOLIS.

95. We now proceed to consider "the present water supply to the metropolis."*

We have accounts of the existence, at a very early date, of artificial works for the water supply of London, in the form of certain conduits, some of whose names still survive in *Conduit Street*, *Lambs Conduit*, and *White Conduit*, and the object of which was to bring for the use of the inhabitants the waters of local springs; but about the middle of the sixteenth century the metropolis had so increased in extent that these were no longer sufficient, and attention became directed to procuring supplies, by mechanical means, from the fine river running close to the city walls.

96. The first systematic attempt to supply London from the Thames was made by Peter Morrys, an ingenious Dutchman, who in 1581 obtained the consent of the corporation to erect a water-wheel under one of the arches of London Bridge; this, being turned by the tidal stream, worked forcing pumps, which impelled the water through the leaden or wooden pipes in the streets, and thence by branches into the houses. The *London Bridge Waterworks*, thus established, subsequently increased in magnitude, and kept up a considerable supply for two hundred years.

97. But as London extended, Morrys's mains and pumping power were, in that infant state of hydraulic science, insufficient to supply the higher and more remote parts of the town, and attention became redirected to sources inland. In 1606 an Act of Parliament was obtained to enable the corporation to bring a stream of clear pure water to the metropolis, from certain copious springs in the chalk at Chadwell and Amwell, near Ware; but the corporation, alarmed probably at the magnitude of the plan, hesitated to commence the works, and nothing was done until, in 1609, an enterprising citizen, Mr. Hugh Myddelton (afterwards Sir Hugh Myddelton, baronet) offered to execute them single-handed, on condition that the authority obtained from Parliament should be transferred to him. This offer was accepted, and he at once commenced the work; but through a complication of difficulties, and the refusal of the corporation to aid him (although he had brought his canal to within a few miles of London), he was compelled to appeal to King James I. for the means of completing his work. The King furnished the necessary grant of money on condition that half the property in the undertaking should be ceded to him, and in September 1613, the canal, then dignified with the name of the *New River*, was completed, conveying the pure Hertfordshire spring water into the reservoirs at Clerkenwell. Thus was introduced into the metropolis a true systematic "water supply by gravitation," after the manner of the ancients.

98. The New River and the London Bridge works, aided by the local springs, with many public pumps and shallow wells, kept the greater part of the metropolis well supplied with water for the whole of the seventeenth century; but as buildings began to extend westward new demands arose. Soon after the opening of the New River, the chalk springs had been supplemented by tapping the River Lee, near to them, but parts of London required water where the London Bridge and New River mains did not reach, and again the Thames was resorted to for an increased supply. In 1691 a company was formed, called the *York Buildings Waterworks Company*, for supplying a part of Westminster with water pumped from a point in the river near Charing Cross. These works flourished for some time, but were in 1818 leased to the New River Company, and in 1829 were abolished altogether.

In 1723 a more successful attempt was made in the establishment of the *Chelsea Waterworks* for supplying Westminster and the parts adjacent with water from the Thames at Chelsea Reach. The company first purchased some small works at Millbank, but afterwards removed to a site near the foot of the present Victoria railway bridge, where they erected a pumping establishment.

* The information in this part, where not obtainable from official documents, has been taken from Mathews's "Hydraulia" and Weale's "London in 1851," or gained by communication with the officers of the companies.

99. The portion of the metropolis south of the river was supplied at a very early date by two wheels erected under London Bridge near the Surrey shore, and by separate works not far distant.

In 1785 the *Lambeth Waterworks Company* was established for supplying the parish of Lambeth and parts adjacent with water pumped from the Thames at a site opposite Charing Cross.

100. During the eighteenth century the existing waterworks were gradually enlarged and improved, and iron street pipes were introduced in lieu of wooden ones, a change which not only enabled the old works materially to extend their supplies, but gave a great advantage to new companies entering the field in competition with them.

101. In 1806 the *West Middlesex Water Company* was established for supplying the western suburbs from the Thames at Hammersmith; and in 1811 another company was formed who availed themselves of power granted by a clause in the Grand Junction Canal Company's Act for supplying, to the north-west of London, water brought by the canal from the rivers Colne and Brent, and from a large reservoir supplied by land drainage in the same neighbourhood. These waters were represented to be much superior to that of the Thames; but experience disappointed the hopes of the projectors; the water was found not only bad in quality, but deficient in quantity; and after vain expedients to remedy the evils, the company, which had taken the name of the *Grand Junction Waterworks Company*, resorted in 1820 to the Thames, taking their entire supply from a point near Chelsea Hospital.

102. While these works were going on in the west, the inhabitants of the other part of the metropolis had not been idle. The districts eastward, beyond the reach of the mains of the New River or London Bridge works, had hitherto been dependent on two small establishments at Shadwell and West Ham; but as the population increased, and further supplies became necessary, a company was established under the name of the *East London Waterworks Company*, for supplying water from the River Lee. Their Act was obtained in 1806; they immediately erected works at Old Ford, near Bow, and soon spread their mains over an extensive district.

In the south districts a new company was established in 1805 called the *Vauxhall Waterworks Company*; they took water from the River Effra, and afterwards from the Thames near Vauxhall Bridge. In 1822 the two ancient establishments at and near London Bridge, supplying Southwark, were combined under the name of the *Southwark Waterworks*.

103. By about the year 1820 the various water companies whose rise we have chronicled above had established a firm footing, and rendered themselves necessary to the inhabitants of London, in respect of the supply of this vital element of health. But the records show that no sooner did they become aware of this fact than they began to take advantage of it for their own interest, by combining together to raise their rates. The public complained loudly of this, and in 1821 a Committee of the House of Commons was appointed to inquire into the whole subject. They made a comprehensive report, in which, while they admitted that "a material improvement had taken place in the supply, both in "respect of abundance and certainty," they recommended that the maximum rates to be charged should be settled by Act of Parliament, and other salutary regulations enforced. No legislation followed this, but it seems to have had its effect in inducing the companies to remove the chief causes of complaint.

104. In a few years, however, discontent arose on another ground, namely, as to the *quality* of the water. The companies had hitherto pumped it into the districts just as it came to hand, without being over particular as to the state it was in. But it was seen that the water of the river was dirty and turbid, and an alarm arose that it must be unwholesome. Accordingly, in 1828, a Royal Commission consisting of three eminent scientific men—Mr. Telford, civil engineer, Professor Brande, chemist, and Dr. Roget, secretary of the Royal Society—was appointed to inquire into "the description, the quality, "and the salubrity of the water" supplied to the metropolis. They had careful examinations and analyses made, from which it appeared that the Thames water when free from extraneous substances was in a state of considerable purity, containing only a moderate degree of saline contents, and those of a kind which could not be supposed to render it unfit for domestic purposes, or injurious to health; but as it

approached the metropolis it became loaded with a quantity of filth which rendered it disgusting to the senses and improper to be employed in the preparation of food.

It appeared, however, that a very considerable part, if not the whole, of this extraneous matter might be removed by filtration through sand, and the Commission took into consideration various plans for effecting this object, which led them to the opinion that it was perfectly possible to filter the whole supply with the requisite rapidity and within reasonable limits of expense.

The general conclusion of the Commission is expressed in the following paragraph:—

"Taking into consideration the various circumstances to which we have now adverted, together with the details of evidence by which they are proved and illustrated, and also the facts derived from our own observation and experience, we are of opinion that the present state of the supply of water to the metropolis is susceptible of, and requires, improvement; that many of the complaints respecting the quality of the water are well founded, and that it ought to be derived from other sources than those now resorted to, and guarded by such restrictions as shall at all times ensure its cleanliness and purity."

From other passages in the report it is clear that the Commission attributed the pollution of the Thames water to its reception of the sewage and refuse from manufactories in the neighbourhood of London, operating within the tideway; it does not appear that they contemplated the possibility of any such large measure as the removal of the companies' points of intake above the range of the tidal flow.

105. Stimulated by this report, and alarmed probably at the prospect of a sweeping change of the sources of supply, the companies directed their attention to the purification of the water by filtration. This process had been well known on a small scale as a means of separating from water any impurities held in suspension, but its application to large public works was a novelty. It was soon found that the only appropriate material for mechanical filtration on a large scale was fine sand; but the great practical difficulty was to prevent the sand from becoming clogged, and to find an easy, practical, and cheap method for its renewal. After much consideration and long-continued experiments a means was discovered of getting over these difficulties. It was found that by far the greater quantity of the impurities were held in suspension by the agitation and motion of the water, and that if it was allowed to stand for some time at perfect rest, in a reservoir, the heavier and grosser particles were deposited by simple subsidence, leaving only a small proportion of lighter and finer matters to be dealt with by filtration. It was also found that when the water was allowed to filter downwards through a porous bed of sand, held up in its place by underlying layers of coarse gravel, the dirt did not penetrate into its mass, but was stopped at the upper surface, so that the whole cleaning operation necessary was to scrape this surface off to a slight thickness, and when it had become too much diminished to put fresh sand on.

The plan of filtration thus matured was at once carried into practice. The first large filter, of one acre area, was set to work by the Chelsea Company in 1829. It was found to work well, and the principle has since been universally adopted.

The other companies, though they did not all adopt the new principle of filtration, made improvements in some way or other. The New River Company constructed extensive settling reservoirs, as did also the West Middlesex Company; the Grand Junction Company removed their source of supply from Chelsea to Brentford, and formed filters there; the East London went higher up the Lee; and the Southwark and the Vauxhall Companies amalgamated, abolished their old sites, and established new joint works at Battersea. The Lambeth Company also formed elevated reservoirs at Brixton Hill and Streatham, to improve the service generally, and to maintain a supply in cases of fire.

106. It would seem, however, that the public had not full confidence in the improvements thus made, for in consequence of the report of the Commission of 1828 the House of Commons recommended that Mr. Telford should look out for new sources of supply, and he was accordingly instructed by the Government to take steps for the purpose. In 1834 he made his report, advising that the northern part of the metropolis should be supplied from the River Verulam above Watford, and the southern part from the Wandle. This report occupied the attention of the House of Commons in 1834, and of the House of Lords in 1840, but nothing was done.

107. The system of filtration was found to work well, so long as the impurities it professed to remove were only mechanical, and were not too great in amount; but it was found that the state of the river was gradually deteriorating, and, what was more

important, that it was becoming fouled in a way that filtration was powerless to purify, namely, by contamination of a chemical nature.

Drainage and sewage works were beginning to be more developed; ideas of what is now called sanitary science were arising; cesspools were beginning to be abolished; and as a consequence much larger quantities of sewage matter began to be poured into the river on all parts of its passage through London. These impurities were carried backwards and forwards by the tide, and their evil effect on the state of the river was enhanced by another circumstance which took place about this time, namely, the introduction of the small local steam boats plying on the Thames above London Bridge, the agitation caused by which not only kept the infused matter in continual mixture with the water, but washed and stirred up the mud at the bottom, which had before lain undisturbed. It was seen that these evils would go on increasing, and would shortly render the water so contaminated as to be beyond the possibility of purification by ordinary means.

108. The first steps towards meeting this difficulty were taken by the Lambeth Company. They had hitherto drawn their water from a site where the bad state of the Thames made itself very obvious, and after well considering the matter, they came to the decision that no measure short of the removal of the source of supply to a point above the highest range of the tide (Teddington lock) would be of any permanent benefit to the quality of the water. They therefore selected a point of the Thames a little above Kingston as their new source, proposing to establish large pumping engines there, and to force the water along a large main of ten miles in length to their existing reservoirs on Brixton Hill. An Act authorizing the works was obtained in 1848, and in 1851 the supply from the new source was delivered to the consumers.

109. Meanwhile the subject of the metropolitan water supply had been taken up by a public body who at that time assumed authority on all matters of a sanitary nature—the General Board of Health. In May 1850 this board issued a long report on the subject, which was followed shortly afterwards by numerous appendices and documents in explanation and justification. They pointed out the evils of drawing water from the Thames within the tideway, where it was exposed to sewage contamination; but not content with this, they objected to the Thames altogether, on the ground of its hardness, as they had adopted the idea that only very soft water was fit for public consumption. They therefore made a recommendation in the following terms:—"Whilst we believe "that Thames water, taken up beyond the influence of the metropolitan drainage, and "filtered, may be used without injury to the public health, and may be employed "temporarily until other sources can be laid under contribution, we advise that Thames "water and other water of like quality as to hardness, be as early as practicable "abandoned." The Board further directed their attention to finding other sources in substitution for the Thames, and fixed upon a tract of ground, of 150 square miles area, formed by the Bagshot sands and the lower greensands in Surrey, from the drainage of which they recommended that the supply for the metropolis should in future be taken.

110. This report was considered by a Committee of the House of Commons in the same year, but they did not endorse the opinions it contained. It happened that about the same time a company was projected, called the London Spring Water Company, which, on the strength of a favourable report made about ten years before by Mr. Robert Stephenson, proposed to supply the metropolis with spring water from the chalk in the neighbourhood of Watford. The Government, distracted by conflicting opinions, and desiring better evidence than they were yet in possession of, at the beginning of 1851 appointed a commission of three eminent chemists, viz., Professor Graham (now Master of the Mint), Dr. Miller, and Dr. Hofmann, to investigate the quality of the water actually supplied, referring to them also the proposals of the Board of Health and of the Watford Company. The report of this Chemical Commission was given in June 1851. It is a most able document, and as it treats of various matters connected with the subject in a manner which, even at this distance of time, is very pertinent to our inquiry, we shall have occasion often to refer to it hereafter.

The Commission expressed their opinion that the Thames water was perfectly wholesome, palatable, and agreeable; uniform, plentiful, and safe in use; but they recommended that to avoid the liability to contamination by the London sewage, the supply should be drawn at a point above the tidal range. They reported unfavourably of the Board of Health scheme, but drew particular attention to the proposed supply from the chalk at

Watford, which, assuming that the hardness could be got rid of by a softening process suggested by Dr. Clark, they considered much preferable to any other from its greater purity.

111. The result of all these investigations was to lead the Government to the opinion that legislation on the subject was desirable, and in 1851 they introduced a Bill to amalgamate all the companies into one great whole, whereby improvements might be introduced more effectively and economically than by dealing with them singly. It was to be one condition that the new company should be compelled to obtain water from such sources as the Secretary of State might direct.

This proposition, which was long and ably fought between its supporters and the companies, also proved too sweeping for the acceptance of the Legislature, and it was modified, the following session, into an Act (15 & 16 Victoria, cap. 84), which, while it did not interfere with the property of the companies, imposed on them many new and important conditions.

112. It is this Act which now regulates the general water supply of the metropolis. It is entitled "An Act to make better provision respecting the Supply of Water to the "Metropolis," and it received the royal assent the 1st of July 1852. Its principal provisions are as follow:

Clause 1 provides that it shall not be lawful for any company supplying the metropolis to take water from any part of the Thames below Teddington lock, or from any part of any of the tributary streams within the range of the tide.

Clause 2 stipulates that every store reservoir within five miles of St. Paul's shall be covered; and Clause 3 makes the same provision for aqueducts, unless the water is subsequently filtered.

Clause 4 provides that all water supplied for domestic use shall be effectually filtered, unless it be pumped from wells direct into covered reservoirs.

Clauses 15 and 22 provide for a constant supply at high pressure being given where demanded by four fifths of the inhabitants of any district, on certain conditions being complied with by them.

Clause 16 makes any company liable to a penalty of 200*l.*, and 100*l.* per month in addition, for violation of the Act, or neglect to comply with its provisions.

The other clauses are of minor importance to our present inquiry.

113. After the passing of this Act the water companies proceeded to comply with its more important provisions, expending about 2,500,000*l.* in works for this purpose; and in 1856, the Government caused chemical and engineering examinations to be made, under the direction of the General Board of Health, to ascertain the results of the changes. The chemical report was made by Professor Hofmann, and Mr. Lindley Blyth, and it showed that while the hardness and solid contents of the water remained about the same, there was a very positive and considerable diminution in the amount of organic matter. This, though doubtless due chiefly to the removal of the intake above the tideway of the Thames, was also attributed in great degree to the considerable improvement which had taken place in the collection, filtration, and general management of the supply of water. The engineering report made by the inspectors of the Board of Health gave a satisfactory account of the new works of the various companies, and of the manner in which they had carried out the provisions of the Act of Parliament. It was suggested, however, that further inquiry should be made into the removable causes of contamination of the Thames above the new sources of supply, and the inspectors recommended the introduction of the constant service system.

114. London is now supplied with water by eight companies, five on the north side of the river, viz.,

The New River Company,
The East London Company,
The Chelsea Company,
The West Middlesex Company,
The Grand Junction Company;

and three on the south side, viz.,

The Lambeth Company,
The Southwark and Vauxhall Company,
The Kent Company.

Each of these companies supplies a certain district, marked by definite boundaries, the whole metropolis being mapped out between them. These districts, together with the sites of the principal pumping stations, filters, mains, and reservoirs, are shown in colours on the map attached to this Report, and marked Appendix AV.

Formerly different companies were often engaged in competition with each other over the same ground; but this course, while it produced no substantial good to the public, was so hurtful to the companies themselves, that it was put an end to by separate limits being assigned to the operations of each company.

115. The *New River Company* supply a very large district, comprehending the whole of central London. The western boundary is a line drawn from Charing Cross by the Haymarket, Tottenham Court Road, and Hampstead Road, northwards to Highgate; the eastern boundary is a line running directly north from the Tower to Stamford Hill.

This company derive the great bulk of their water from sources in the valley of the River Lee, near Hertford, namely,

1. From a copious spring called the Chadwell Spring, situated between Hertford and Ware.
2. From wells sunk into the chalk at Amwell, near Ware, and at Hoddesdon and Cheshunt, a little lower down the valley.
3. From the River Lee itself, in the same neighbourhood.

The waters from these sources are united and conveyed to London by an artificial channel, called the "New River." The distance of the sources from London in a direct line is about 20 miles, but as the New River winds considerably, in order to take advantage of suitable levels of the ground, its course is much longer. The original length was nearly 40 miles, but it has been lately shortened by extensive cuts, leaving its present length only about 28 miles. It is an open river, protected by fencing, for about 25½ miles of its course, the remainder being tunnel or pipe.

The average dimensions of the New River are about 18 feet wide and five feet deep; in its original course it had an average fall of about five inches in each mile of length; but the diminution of length has given a much greater proportionate fall, and has consequently much increased the quantity of water it is capable of conveying.

Leaving Ware, the New River turns southward, and passes through or near Broxbourne, Cheshunt, Enfield, Winchmore Hill, Hornsey, Stoke Newington, Ball's Pond, and Islington, to a site at Clerkenwell known by the name of the New River Head. The water is allowed to subside in reservoirs at Stoke Newington and Clerkenwell, having a joint area of 43½ acres. In addition to the supply brought by the New River, the drainage of a small district, of three or four square miles area, is collected by two reservoirs at Cheshunt of 18½ acres area; this water is admitted into the New River as required. The filtering reservoirs are at Stoke Newington, Hornsey, and Clerkenwell, and occupy 11¼ acres.

At Stoke Newington, Hornsey, and Clerkenwell, there are large pumping engines for forcing the filtered water into store reservoirs at a higher level, situated at Claremont Square and Maiden Lane; and near the Archway, Highgate, is another pumping station, which forces water into still higher reservoirs at Highgate and Hampstead. These reservoirs contain in the aggregate about 20 millions of gallons, and are covered in as required by the Act.

From these reservoirs the district is now supplied, and to meet the varieties of level in the several localities, the district has been divided into several distinct levels, each having its own reservoirs and separate systems of supply. The whole pumping power of the company amounts to nearly 1,700 horses. The length of their mains is about 620 miles.

The company have an engine at Tottenham, by which they can, when necessary, obtain water directly from the Lee, taken at the same point of the river as the water of the East London Company; but this is only intended to be used in case of emergency, such as accident, or stoppage by frost, &c. They have also power to draw water from the Thames below Blackfriars Bridge, to be distributed by separate mains for street watering and sewer flushing, the use of this for the general supply being forbidden by the Act of 1852. It is stated that neither of these supplementary supplies has been used for several years.

The company have further a deep chalk well in the Hampstead Road, and also one formerly belonging to the Hampstead Waterworks, taken by them a few years ago; both these wells, though not at present used, are available to increase the general

supply. They also took to the Hampstead Company's springs and ponds at Hampstead and Highgate, the water of which is used only for street watering.

116. *The East London Waterworks Company* supply also a very large area, comprising the whole of London eastward from the boundary of the New River district, and extending from the St. Katherine's docks to North Woolwich, and from the line of the Shoreditch and Kingsland roads to Woodford.

The supply is derived from the River Lee at Higham Hill, in the parish of Walthamstow, about nine miles above the junction of the Lee and the Thames.

The company have reservoirs at Walthamstow containing about 110 acres of water area, and capable of holding 220 millions of gallons, 170 millions of which can be withdrawn by simple sluices, and the remainder by pumping.

From these reservoirs the water passes by a special private canal about $1\frac{1}{4}$ mile in length to the filtering beds at Lee Bridge, which are 13 in number, divided into two series, and having a united area of 12 acres on the surface of the sand; and after filtration it passes to large pumping engines established at two stations, Lee Bridge and Old Ford.

From the universal flatness of the district this company have no elevated reservoir, but the supply is afforded by the continuous working of one or more engines, and the pressure is kept up by high stand pipes attached to the pumping mains.

They are now executing works for bringing an additional supply from the Thames, under powers to which we shall allude more particularly hereafter.

117. *The Chelsea Waterworks Company* supply a district extending from Charing Cross westward to Fulham, and from the Thames northwards to the Uxbridge Road, and comprehending Chelsea, Knightsbridge, the whole of Belgravia and Pimlico, and a large portion of Westminster.

The water is taken from the Thames at a point on the right or south bank, at Long Ditton, nearly opposite Hampton Court Palace, three miles above the highest range of the tide. It is first allowed to subside in reservoirs constructed for the purpose, and then filtered through sand and gravel, after which it is pumped by steam engines through two large cast-iron main pipes, six miles long, to elevated covered reservoirs, containing 20 millions of gallons, on Putney Heath. From this the water flows, by its own gravity, through mains passing over the Thames at Putney into the company's district.

118. *The West Middlesex Waterworks Company* supply a district extending west of Tottenham Court Road and north of Oxford Street, as far as the Edgware Road, and in addition a large western suburban area, including Kensington, parts of Fulham and Brompton, Hammersmith, Chiswick, &c., and as far north-west as Hendon.

The water is taken from the Thames on the north bank, at a point a little above the town of Hampton, and $5\frac{1}{2}$ miles above the termination of the tidal range at Teddington lock. From this point it is passed by pumping power, through a cast-iron main 36 inches diameter, and $8\frac{3}{4}$ miles long, crossing the river to a site at Barnes, from which the company formerly took their supply. Here the water is first allowed to subside in reservoirs of $20\frac{1}{2}$ acres area, and then filtered in five filter beds of about eight acres. It then crosses again under the bed of the river to the north bank at Hammersmith, where the pumping station is situated for supplying the district. There are two elevated covered reservoirs, one at Kensington, containing about $3\frac{1}{2}$ millions of gallons; the other on Primrose Hill, at a high level, containing $4\frac{3}{4}$ millions of gallons. For some parts which lie higher it is necessary again to pump, from Primrose Hill, into another more elevated covered reservoir, containing $2\frac{1}{2}$ millions of gallons, at Hampstead.

119. *The Grand Junction Waterworks Company's* district comprehends that part of the parish of St. George, Hanover Square, which lies north of Piccadilly, a small portion of Marylebone, the larger part of Paddington, and St. James's to Pall Mall.

They take water from the Thames, close to the point of the West Middlesex supply, and force it along a 33-inch main to Brentford, $7\frac{1}{4}$ miles distant. It is allowed to subside in reservoirs partly at Hampton and partly at Brentford, covering $8\frac{1}{4}$ acres, then filtered in beds occupying $5\frac{1}{6}$ acres, and then is pumped into the district, there being an elevated covered reservoir on Camden Hill, Bayswater, containing 6,000,000 gallons, with additional engine power for still higher levels.

120. *The Lambeth Waterworks Company* supply a large district on the Surrey side

extending from the Thames on the north to Croydon on the south, and from Lewisham and Beckenham on the east to Thames Ditton and Esher on the west.

They take their water from the Thames near Long Ditton at the place adopted by the Chelsea Company. Here filter beds and pumping engines are established, forcing the water along a cast-iron main, $10\frac{1}{4}$ miles long and 30 inches diameter, to elevated covered reservoirs at Brixton, containing 12,000,000 gallons; from these it flows by gravity into the whole of the low-lying district, and is again pumped to supply higher covered reservoirs at Streatham, Selhurst, and Rock Hill, the highest service given being at Norwood, about 350 feet above the Thames.

121. *The Southwark and Vauxhall Water Company* supply a still larger district, comprising the borough of Southwark, portions of Lambeth and Clapham, and the whole of Battersea, and extending east to Rotherhithe, west to Richmond, and south to Camberwell. In some parts supplies are given both by this and the Lambeth Company.

They obtain water from the Thames above Hampton, at the same site as the West Middlesex and Grand Junction, and it is forced along a 36-inch main 13 miles long to their old establishment at Battersea, where it is pumped by large engines directly into the district mains; like the East London they have no elevated store reservoirs. There are large subsiding reservoirs and filters, both at Hampton and at Battersea.

122. *The Kent Waterworks Company* supply the whole of the south-eastern suburbs, their district comprising Deptford, Greenwich, and Woolwich, and extending from Camberwell to Dartford, and from the Thames southward to Bromley, Chiselhurst, and Bexley.

This company was incorporated in 1810, when they took possession of some ancient works on the river Ravensbourne at Deptford, established as early as 1699. Down to 1857 they continued to take water only from this source, but the river proving insufficient, the supply was then supplemented by wells sunk into the chalk, and, this source proving so much more plentiful and so much better in quality, in 1862 the Ravensbourne was entirely abandoned.

The principal station is at Deptford, where there are three wells on the site of the old works, each with a pumping engine, the water being conveyed for distribution to other engines, which pump directly into the district mains. There are also two wells at Charlton, one at Plumstead, one at Crayford, and one at Bromley; at each of these wells an engine is placed which serves both for pumping and for distribution.

In addition to the pumping power at the different wells, there are other engines near Shooters Hill for supplying the more elevated districts, and there are elevated reservoirs in Greenwich Park, on Woolwich Common, and at Plumstead and Chiselhurst, to regulate the pressure, and keep up a supply in case of fire. The water does not require filtration.

The following data refer to the wells furnishing this company's supply:—

	Maximum Quantity pumped (Gallons per hour).	Levels with reference to Ordnance Datum, in feet.			
		Of Surface of Ground.	Of Bottom of Well or Bore-hole.	Of Surface of Water when not pumping.	Of Surface of Water when pumping Maximum Quantity.
3 Deptford wells -	287,000	+20	−230	+12	− 44
2 Charlton wells -	70,000	+25	−225	+10	− 45
Plumstead well -	57,000	+80	−420	+10	− 20
Bromley well - -	25,000	+120	−130	+115	+103
Crayford well -	38,000	+30	−120	+20	+ 14

123. In addition to the supplies of the water companies, there is a considerable quantity of water furnished from wells sunk, in 1844, by Messrs. Easton and Amos, on behalf of the Government, near Charing Cross. They are nearly 400 feet deep, penetrating into the chalk, and they furnish a quantity of about 430,000 gallons per day, which is used to supply the Government offices and several public establishments in Westminster and the neighbourhood, and the fountains in Trafalgar Square.

A small further addition to the supply of the suburbs of the metropolis is obtained from the chalk springs at Grays, in Essex, described in Mr. Meesom's evidence, and alluded to in Part II. of our Report. A company was incorporated in July 1861 for this purpose, under the name of the South Essex Water Company, and a pumping establishment was formed at Grays, with a store reservoir at Brentwood, and distributing mains ramifying in various directions. The water is now delivered at Brentwood, Shenfield, Warley (including the great barracks there), Grays, and several neighbouring villages. The quantity pumped is about 450,000 gallons per day, and the number of inhabitants supplied between 15,000 and 16,000.

124. The following table gives the statistics of the principal water companies in a combined form:—

Statistics of present London Water Supply.

——	Capital.	Approximate Area of District supplied.	Number of Houses supplied, 1867.	Estimated Number of Inhabitants supplied, 1867.	Average daily Supply, 1867.
From the Thames.	£	Square miles.			Gallons.
Chelsea Company - -	785,600	6½	26,875	170,000	8,087,258
West Middlesex - -	798,571	10	36,881	275,000	8,816,486
Grand Junction - -	850,000	24	27,190	245,000	9,533,432
Southwark and Vauxhall -	1,100,440	30	71,558	465,000	13,629,758
Lambeth - - - -	736,245	25	38,320	230,000	8,975,530
					49,042,467
From the Basin of the Lee.					
New River Company -	2,609,418	19	113,462	800,000	23,790,667
East London Company -	1,400,000	50	92,652	675,000	19,298,241
					43,088,908
From Chalk wells in Kent.					
Kent Company - -	489,240	60	34,504	240,000	6,468,873
Total -	8,769,514	224½	441,442	3,100,000	98,600,248

In reference to the quantity supplied, it must be observed that the amount in the last column expresses only the average daily supply for the whole year; but a reference to the table in Appendix N will show that, as might be expected, the supply is much greater in summer than in winter. The *maximum* daily supplies in June or July were as follows:—

	Gallons.
Chelsea - - - - -	9,042,800
West Middlesex - - - -	9,776,707
Grand Junction - - - -	11,032,742
Southwark and Vauxhall - - -	13,975,000
Lambeth - - - - - -	10,257,800
New River - - - - -	26,710,000
East London - - - - -	20,321,152
Kent - - - - -	7,196,708
Total - -	108,312,909

This shows that the maximum daily quantity supplied in the summer months is about 10 per cent. in excess of the average of the whole year, and this is an important fact in considerations affecting the quantity of water required.

The following table gives particulars of the reservoirs, filter beds, and pumping engines of the various companies:—

WORKS OF THE COMPANIES.

Subsiding Reservoirs.		Filter Beds.		Store Reservoirs.			Pumping Engines.	
Number and Situation.	Area in Acres.	Number and Situation.	Area of Sand Surface in Acres.	Number and Situation.	Available Contents in Gallons.	Height of High-water Line above Ordnance Datum.	Number and Situation.	Horse Power.
CHELSEA COMPANY.						Feet.		
3 at Seething Wells, near Kingston, with vertical rough filters attached.	4½	2 at Seething Wells, near Kingston. NOTE.—Two additional filter beds similar to the above are in course of construction at Seething Wells.	2	2 for filtered water, situate on Putney Heath.	10,000,000	182½	8 at Seething Wells, near Kingston.	1,025
				1 for unfiltered water, situate on Putney Heath.	1,000,000	182½		
WEST MIDDLESEX COMPANY.								
3 at Barnes, Surrey -	20½	5 at Barnes, Surrey -	8	1 at Kensington -	3,672,000	124½	2 at Hampton - -	210
				1 at Barrow Hill -	4,750,000	190	5 at Hammersmith -	900
				1 at Kidderpore -	2,500,000	323	2 at Barrow Hill -	85
							1 at Barnes (for sand washing machines).	6
GRAND JUNCTION COMPANY.								
2 above Hampton -	2	3 at Kew Bridge -	5½	1 at Campden Hill -	6,000,000	132½	2 at Hampton - -	220
2 at Kew Bridge -	5½			2 „ „ -	12,000,000		4 at Kew Bridge -	660
1 „ -	3½						2 at Campden Hill -	300
SOUTHWARK AND VAUXHALL COMPANY.								
2 above Hampton -	2	5 at Battersea - -	8	None - - -	None -	None.	3 at Hampton - -	400
2 at Battersea - -	6½	3 at Hampton - -	3				6 at Battersea - -	915
1 at Hampton - -	3½						2 at Hampton - -	450
LAMBETH COMPANY.								
3 at Long Ditton, near Kingston, with vertical rough filters attached.	3	4 at Long Ditton, near Kingston.	1½	2 at Brixton - -	12,000,000	115½	7 at Long Ditton, near Kingston.	970
				1 at Streatham -	3,750,000	197½	5 at Brixton - -	210
				1 at Rock Hill (Sydenham).	500,000	362½		
				1 Ditto ditto	115,000	385½		
				1 at Selhurst (near Croydon).	2,500,000	218½		
				1 at Coombe (near Kingston).	1,150,000	192½		
NEW RIVER COMPANY.								
2 at Stoke Newington	12½	7 at Stoke Newington	7	1 at Claremont Square	3,500,000	139	8 at Stoke Newington	1,080
1 at New River Head	¾	3 at New River Head	2¼	2 at Maiden Lane -	15,000,000	232	2 at New River Head	200
2 at Hornsey - -	8	3 at Hornsey - -	2	1 at Highgate - -	1,000,000	432½	1 at Hornsey - -	75
2 at Cheshunt - -	18½			1 at Hampstead -	500,000	447½	2 at Highgate - -	75
13 at Highgate and Hampstead (for street watering only).	30			1 at Camden Park Road (uncovered, for unfiltered water).	900,000	171½	1 at Amwell End -	50
							1 at Amwell Hill -	25
							1 at Hoddesdon -	50
							1 at Cheshunt -	20
							2 at Tottenham -	125
EAST LONDON COMPANY.								
5 at Walthamstow, Essex.	110	13 at Lea Bridge -	12	1 at Old Ford - -	7,000,000	12½	6 at Old Ford (steam)	640
							4 at Lea Bridge (ditto)	600
							2 Ditto (water)	65
							1 at Walthamstow (steam).	100
							1 at Walthamstow (water).	30
KENT COMPANY.								
None.		None.		1 on Woolwich Common.	325,000	314	7 at Deptford.	740
							2 at Charlton.	238
				1 on Plumstead Common.	750,000	170	1 at Plumstead.	63
							1 at Bromley.	33
				1 on Chiselhurst Common.	450,000	306	1 at Crayford.	54
							2 at Dover Road.	47
				1 in Greenwich Park (uncovered).	1,125,000	163		
				1 on Woolwich Common (uncovered).	1,600,000	240		

125. The distribution of the water is on what is called the *intermittent* system. The supply pipes to the houses are not attached to mains in which the water is always under pressure, but to smaller service pipes, into which the water is "turned on," as it is called, during only one or two hours each day, the consumers receiving during this short time the whole quantity required for the day's consumption, and storing it for use in cisterns provided by themselves. On Sundays, as a general rule, no supply is given, but exceptions are made by many of the companies in poor neighbourhoods where the receptacles are insufficient.

126. We may now allude to the more recent public proceedings affecting the water supply of the metropolis.

In 1865 a Royal Commission was appointed to inquire into the best means of preventing the pollution of rivers, embracing also the question of water supply. In March 1866 they reported on the River Thames; and their report, so far as bears on our present inquiry, was to the effect that the river was at present fouled by various causes, but principally by the sewage of towns, villages, and houses on its banks, but that this sewage might be so utilized on land as to be rendered innocuous. They recommended that the whole river should be placed under the superintendence of one governing body, who should amongst other duties take steps to ensure its freedom from pollution.

This recommendation bore immediate fruit, for on the 6th of August in the same year an Act (29 & 30 Vict. cap. 89) was passed, altering the constitution of the existing Conservancy Board of the Thames, and considerably enlarging their powers. It extended their jurisdiction up to Cricklade in Wilts, and made two important provisions for ensuring the purity of the water:—

1. The surface of the river was to be effectually scavenged, in order to the removal therefrom of substances liable to putrefaction.
2. The admission of sewage or any other offensive or injurious matter into the Thames, or into any tributary stream or watercourse within three miles of its junction with the Thames, was declared illegal, the Conservators giving due notice to all offending parties to discontinue the practice under heavy penalties.

To enable towns and villages more easily to comply with the requirements of this law, there was passed in August of the next year an Act (30 & 31 Vict. cap. 113) for facilitating the distribution of sewage matter over land, and otherwise amending a law previously passed with the same view.

127. In May 1867 the Rivers Pollution Commission made a report on the River Lee, which they found liable to pollution from sewage and refuse from manufactories, and beset with peculiar difficulties as to its purification and general management; they recommended certain measures with a view to improvement.

During the same session, the East London Waterworks Company, who were requiring to increase their supply, applied to Parliament for powers to enlarge their works; and having been led by the experience of the extreme dry season of 1864 to distrust the capability of the River Lee to afford all they wanted, they promoted a bill for enabling them to draw 10,000,000 gallons per day from the Thames at Sunbury. Both these bills were passed, with certain controlling provisions.

It had happened, however, that in the previous year there was a severe outbreak of cholera in the east of London, and, from certain peculiarities in the phenomena exhibited, suspicion was entertained that it might be connected with the water supply. The suspicion was strengthened by the circumstance that the Registrar General for the metropolitan districts had established a monthly analysis of the water supplied, and that his reports had produced an impression unfavourable to the quality. When therefore the East London bill was referred to a Committee of the Commons, the House took the opportunity of instructing them to inquire generally into the operation and results of the Metropolis Water Act, 1852, of which, as it came into full operation in 1856, ten years' experience had been gained.

128. This committee, of which Mr. Ayrton was chairman, inquired fully into the whole subject, and reported at the end of June 1867.

As to the main question, they declared they were satisfied that both the quantity and quality of the water supplied from the Thames were so far satisfactory that there was no ground for disturbing the arrangements made under the Act of 1852, and that any attempt to do so would only end in entailing a waste of capital and an unnecessary charge upon the owners and occupiers of property in the metropolis.

The water of the Lee they found naturally not only wholesome, but comparing favourably with that supplied to other places. They agreed with the Rivers Commission that it was liable to serious contamination, but they suggested certain alterations in the remedial measures proposed, and expressed their opinion that when these were carried out the water supplied by the companies would be of unquestionable character.

They also approved the North Kent water, and considered this company had an adequate command of quantity for many years to come.

They went elaborately into the question of constant supply, and recommended that it should be enforced, under strict provisions to prevent waste, and to ensure the suitable condition of all the house fittings.

They finally recommended that the duty of seeing that the water companies properly fulfilled their obligations should be imposed on the Metropolitan Board of Works; and that a new Act should be passed consolidating all the laws at present in force as to the metropolitan supply, and introducing the new measures they had proposed.

129. In 1868 an Act (31 & 32 Vict. cap. 154) was passed to make better provision for the preservation and improvement of the River Lee and its tributaries. It was analogous to the Thames Conservancy Act of 1866, altering the constitution of the managing body, and rendering illegal the admission of sewage or offensive matter into the river, except in the case of certain towns where measures had been adopted for its purification.

PART IV.

ON THE SUPPLY OF WATER AVAILABLE FROM THE BASIN OF THE THAMES.

130. We have now to consider the eligibility, for the future service of the metropolis, of the great source from whence its supplies have hitherto been drawn, namely, the basin of the River Thames.

The gigantic schemes proposed for supplying London with water gathered in the distant mountain ranges of the country have been projected on the assumption that the nearer and more natural supply derived from the Thames valley was either deficient in quantity or unsuitable in quality, or both. It becomes, therefore, our duty to inquire whether there is sufficient justification for either of these suppositions; and we will consider them each in turn.

Section I.

AS TO QUANTITY.

131. At the end of Part II. of this Report we have endeavoured to give a general view, scientifically considered, of the most important natural features of this great basin, having reference particularly to its underground storage, and the nature and distribution of its springs. It will be here our object more practically to consider the evidence as to the quantity of water actually obtainable from the rivers and wells in this district.

On this point we have received a large amount of information from a great number of witnesses, who, from their position, experience, and knowledge, are most competent to judge of the subject.

132. The portion of the basin first to be considered is that above Hampton and Ditton, where the water companies have their intake. This portion extends over a length and breadth of 80 or 90 miles, its superficial area being given as 3,676 square miles.

The Thames first assumes importance near the small town of Lechlade in Wilts, where a number of small streams, forming the head waters of the river, unite. From this point down to Ditton it follows a tortuous course of about 120 miles in length, and is joined on either bank by several important tributaries.

133. The rainfall in the Thames basin has been determined with considerable accuracy by many years' observations by numerous persons at various localities from London to Cirencester. It is found to vary, on an average, from about 25 inches at the former place to 30 inches at the latter. Taking the mean of the whole area, Mr. J. T. Harrison estimates the average rainfall to be 27¾ inches, and of this it is estimated that one-third flows down the Thames. 4671. 6838. 2966. 3036.

134. It is desirable, however, to investigate the volume of the stream more particularly; taking our data at the point most important for our purpose, namely, at the intake of the companies, a little above the highest point reached by the tide, and where the natural fresh water stream has its maximum volume.

It has been shown that the total discharge at Kingston for eleven years was 5,432,418 millions of gallons, which is equal to an average of about 1,350 millions of gallons per day, or equivalent to about nine inches of rainfall. If this were the constant flow, no question could arise as to its sufficiency; but we need hardly say that it varies very widely at different times. In floods the stream is so large as scarcely to admit of accurate measurement; but in dry seasons it is much reduced; and it is in reference to the volume in these seasons that the doubt has arisen. It is therefore to this that we must direct attention. 3904.

135. Several witnesses have spoken to this point; we may first give Mr. Bateman's views as to the supposed deficiency in quantity, which has been one ground why he has considered the Thames ineligible, and has proposed to go to the mountains of Wales. He says:

App. E. "When the Acts of 1852 were passed it was estimated that the minimum quantity of water at Hampton was 362,000,000 gallons per day, and this minimum has been habitually considered, in round numbers, as 400,000,000. During the month of September in this year (1865) the river has been carefully measured above the waterworks at Hampton, and the gross daily quantity for a considerable period together has scarcely exceeded 300,000,000 gallons."

6515*a*–6522. 6540–54. In subsequent evidence he explains that the actual quantity given by his gaugings at Hampton in 1865 was 308,720,000 gallons per day, and he describes fully the mode in which the measurements were taken.

4561–4651. 136. Other witnesses give larger amounts. Mr. Simpson states that he has gauged the quantity flowing down at Kingston daily since 1852, and found the minimum in 1864, the driest year known, was 380,000,000 gallons per day, after the whole of the companies had taken their supply. He adds that this was in extreme drought, the usual flow in dry seasons being seldom lower than 600 to 700 millions of gallons.

3266. Mr. Beardmore states that the mean flow at Kingston in the months of June, July, August, and September, for 1864 and 1865, the two driest years, was between 380 and 390 millions, including the companies' supplies, and the absolute minimum only a little lower.

2931 *et seq.* Mr. John Thornhill Harrison, C.E., member of the Royal Commission on the Pollution of Rivers, (who specially investigated the subject, and during their inquiry received much information on the capacity of the basin for affording a water supply,) has put in an extensive series of tables illustrating the meteorology and hydrology of the Thames basin. Confining our attention to those portions of the tables which illustrate the state of the water in the driest seasons, we find that he has given particulars of the actual discharge in the three years 1858, 1859, and 1864, at the times when the quantity was under 400,000,000 gallons per day, and he shows the number of days in each year when the volume attained certain amounts.

The quantity was below 400,000,000 gallons

In 1858 for 36 days.
„ 1859 „ 32 „
„ 1864 „ 8 „

The lowest quantity noted was 350,000,000 gallons per day, and this was observed

In 1858 for 20 days.
„ 1859 „ 14 „
„ 1864 „ 2 „

4259. Mr. Leach, the engineer to the Thames Conservancy Board, says that having often gauged the river at Teddington, he has never found it less than 380,000,000 gallons per day.

6005–8. Mr. Quick, engineer to the Grand Junction and the Southwark and Vauxhall Companies, says the lowest gauging that has ever been taken of the Thames has amounted to 360,000,000 gallons at Teddington.

All these quantities, except Mr. Bateman's, are below the intake of the water companies, and therefore are exclusive of the quantity abstracted by them, which is at present about 50,000,000 gallons per day.

137. We think from this evidence we may fairly conclude that a daily flow of 350,000,000 gallons per day is a very exceptional thing, occurring only for a few days in the course of many years.

138. The companies are empowered, under their present Acts and agreements, to take as follows:—

	Gallons per day.
Chelsea Company	20,000,000
West Middlesex	20,000,000
Grand Junction	20,000,000
Southwark and Vauxhall	20,000,000
Lambeth	20,000,000
East London	10,000,000
Total	110,000,000

139. We are led to believe that it would be easy to make storage reservoirs and other works on the upper part of the river to collect the flood waters; and that by means of these the flow might be so equalized as to neutralize the effect of the severe droughts, and therefore to admit of a still larger abstraction of water if the growing requirements of the metropolis should render it necessary.

140. We will give a summary of the evidence we have received as to the quantity obtainable from the river.

Mr. Hawksley considers there is capacity in the Thames watershed to supply a sufficient quantity for the metropolis. The companies might take the maximum supply they are entitled to without injury to the river, or interference with the navigation. Below Teddington the river is tidal, and the abstraction of water would not interfere at all with the scour; for this reason, that the upland water of the Thames in its ordinary state has little or no influence upon it. It is chiefly when in flood that it has an influence on the scour, and the floods of the Thames are so enormous that practically the quantity taken by the water companies then disappears from the calculation altogether. The maximum flood in the Thames is about 20,000 to 25,000 millions of gallons per day. He considers that a quantity nearly double the statutory limit might be taken from the Thames without any storing process; half the lowest volume of the Thames (which he calculates at 360,000,000 gallons) might be taken, and he does not believe it would have any sensible influence. 5055–70. 5106–7.

He believes the average flow of the Thames in three consecutive dry years to be about six inches of rainfall, which would give nearly 900,000,000 gallons per day.

If more was wanted than could be taken at present it might be obtained by impounding the flood waters, and there would be no difficulty in finding sites for reservoirs. 5071–3. 5094.

Mr. Simpson is of opinion that, by proper arrangements, the Thames basin is capable of supplying 200,000,000 gallons per day. There is no necessity for making reservoirs at present; there is plenty of water. The supply might be increased considerably, and afterwards might be supplemented by reservoirs to double the amount. But it may be fourteen or fifteen years before such works become necessary. 4572–6. 4596. 4646–7.

He assumes that 200,000,000 gallons could be obtained from the Thames, and 60,000,000 gallons from the Lee, which would, at 30 gallons a head, be sufficient for a population of 8,700,000, and that practically, therefore, the Thames may be looked forward to as able to supply London beyond any probable increase. 4721–2.

Mr. Simpson says, that supposing it desirable that large works should be made in the Thames valley to admit of the supply being increased to four times its present amount, the various companies to be benefited should contribute to the cost of such works, but that their execution and maintenance should be left in public hands. 4587-93.

Mr. Beardmore agrees that by the provision of storage reservoirs for the flood waters it is quite practicable to take a much larger quantity from the Thames than at present, not only without any injury to the river below Teddington, but with very great advantage. He considers that from the Thames and Lee together 300,000,000 gallons may be obtained. 3321. 3328.

Mr. J. T. Harrison is of opinion that reservoirs might be made, in the upper districts of the Thames, sufficient to provide for a very large deficiency in droughty seasons. 3092–100.

The Rev. Mr. Clutterbuck, and Mr. Bailey Denton, whose plans and suggestions we have noticed in Part II., agree in the opinion of the sufficiency of the Thames for any probable requirements for the supply of London, if proper provisions were made for storage. 1839. 1532.

Mr. Rawlinson expresses his opinion that a supply may be obtained from the Thames sufficient for London, both present and future. 1360.

Mr. McClean (whose plan for bringing water from Henley has been noticed in Part II.) is of opinion that by storing the flood waters in the upper reaches of the Thames more water may be obtained than can ever be required. He quotes as follows from a Report on the Thames by the late Mr. Blackwell, who was for many years engineer of the Kennet and Avon Canal:— 3637. 5498 *et seq.*

"In a geological point of view the River Thames is, of all the large rivers in England, that in which we may expect the slowest and most constant influence of the rain that falls. From the basins of its tributaries, the rivers Kennet and Loddon especially, consisting as they do almost entirely of chalk or other pervious subsoil, the water finds its way very slowly; and it is not until after many weeks of drought that any diminution of the quantity they supply is perceived.

"The results of my own carefully repeated experiments quite agree with the conclusions that a scientific consideration of the above data would lead to. The volumes of the Thames at Henley, as well as those of the

Kennet and the Loddon, have been repeatedly gauged, and the results obtained lead me to the conclusion that at the time of the shortest water the quantity passing the point at which we propose to take our supply is not less than 55,500,000 cubic feet, or 345,000,000 gallons daily. This is the minimum of the gaugings, and taken near the termination of an unusually long protracted season of drought."

5746-59. Mr. Thorpe, the acting chairman of the Thames Conservancy Board, is of opinion that the whole quantity of 100,000,000 gallons per day, which the companies are empowered to take, might be abstracted without any evil effects on the river as a navigable stream, and that if certain alterations were made, and certain works executed for storage, the quantity might be exceeded.

3601-13. Captain Burstal, secretary to the same board, considers that an enormous quantity more than is drawn already may be drawn above Teddington lock, without the river feeling it to any great extent. He considers reservoirs might be made above Oxford for this purpose with facility and advantage.

4244 *et seq.* Mr. Leach, engineer to the same board, has never observed any evil effects on the scour from the abstraction of water, nor does he apprehend any, supposing the companies to draw to their full authorized extent. For the greater part of the year the largest abstraction they could make could not be detected in the volume of the river. He thinks the Thames basin and the Thames stream are equal to the growing requirements of the metropolis without injuring the scour.

4300-14. He considers storage reservoirs would be desirable auxiliaries; they would equalize the flow, but still would give sufficient flood action for scouring purposes. There is a district above Oxford well calculated for the formation of reservoirs. The companies might take more than 100,000,000 gallons without reservoirs. With storage reservoirs he thinks 200,000,000 gallons might be taken per day and the river still maintained in a perfect state.

In reference to complaints which are stated to have been made as to the effect of abstracting the water on the upper part of the tideway, he says:—

"I think that more complaint has been made from persons residing in that part than any other of the ill effects which have been presumed to follow the abstraction of the water. In my opinion they have been quite mistaken upon that, they have attributed to the abstraction of the water from the river that which has arisen from an entirely different cause. The fact is that the Thames in the tideway for the last 30 years or more has been undergoing very great changes. The bed of the river in and about London has been depressed by the excavations which have been made in it, but at the upper extremity of the tideway it has remained pretty nearly the same. The consequence is that the inclination from that point down to where the excavations have taken place has become much greater, and consequently the stream is much more rapid, and therefore instead of the normal flow of the river passing off gradually as it did formerly, it now runs off very quickly, producing a much sharper stream in the upper part of the tideway towards the time of low water than there used to be, and whatever supply there is of water is consequently carried off more rapidly."

6005-8. Mr. Quick thinks there is no doubt that the basin of the Thames would be able to supply a larger quantity than the companies have power to take. If it were necessary storage reservoirs might be provided in the upper Thames; but as the companies only take now one-seventh of the minimum flow, it would be a long time before anything of that kind would be required.

It will be seen by the above extracts that there is a general accordance among the witnesses as to the sufficiency of the Thames. Mr. Greaves, however, the engineer of the East London Waterworks, says,—

5182-9. "I do not think these rivers are going to last as long as Mr. Hawksley does; I think it is necessary to be cautious in time; I would not like speculating upon any one of those rivers round London lasting for the next half century; not only the Lee or the Thames, but other rivers; I mean lasting as a source of water supply independent of any foreign aid. I think it is quite a fair thing in prospect to talk about going beyond the Thames basin; that is to say, you will either have to do that or to store very largely, more largely than anyone has entered into the practical estimation of."

At the same time Mr. Greaves adds that he does not think the time is yet come for going beyond the Thames; and when further examined as to his reasons for doubting the capacity of the river, he appears to base them on the assumption of a possible change of climate as affecting the flow.

It is to be regretted that there is almost an entire absence of reliable information as to the flow of the river except at one point. It would be very desirable to establish a series of gaugings of the Thames at various points of its course, and of its chief tributaries, showing the variations at different times.

141. Considering the whole of the evidence above referred to, we believe we are justified in inferring, in the first place, that the quantity at present authorized, namely, 110,000,000 gallons per day, might safely be drawn from the main stream of the Thames in its present state; and, secondly, that by means of proper works for storage this quantity might be doubled if required.

Subsidiary Basin of the Lee.

142. But apart from the main stream of the Thames it is also necessary to inquire into the additional quantity which may be obained from the subsidiary basin of the River Lee. Full information as to this basin is contained in the Report of the Rivers Commission. Its area is about 500 square miles; and the mean rainfall, which is equally well determined with that of the Thames, is given by Mr. Beardmore, the engineer of the river, at about 25½ inches. The upper part, above Hertford, is entirely chalk, the lower part almost entirely London clay.

The two companies who draw water from the river appear to have the right of appropriating the whole flow, with the exception of a quantity of about five millions of gallons per day reserved for lockage on the navigation. The actual mean quantities at present drawn by the companies from the river are:—By the New River 18 millions of gallons per day, taken at the upper part of the river, between Hertford and Ware (this being part of their whole supply of 23¾ millions):—by the East London Company 19¼ millions of gallons, taken lower down:—making on the whole 37¼ millions of gallons per day on the average of the year, the quantity in the summer months being increased to about 40 millions. Adding to this the lockage, it gives a total present demand on the river in the summer of about 45 millions. 3961.

We may now compare this with the quantity naturally flowing down the river.

Mr. Beardmore has given us tables of the flow of water in the Lee for 19 years. He makes the average daily flow at Feilde's weir over this time 108·8 millions of gallons; and in the months of June, July, August, and September, of five dry years, he makes it (including the companies' supplies) average 45·2 millions, which is increased by springs in the valley below the weir. 7444.

It is therefore clear that in dry seasons little or no increase is to be relied on from the river in its present state; the only question is, to what extent might the dry weather flow be augmented by storage reservoirs.

143. The evidence on this point is as follows:—

Mr. Beardmore believes that reservoirs may be made within practicable and reasonable limits of expense, so as to store the winter flood waters, and deliver about 70 to 90 millions of gallons daily. 3313–4. 3438–9.

Mr. Muir, the engineer of the New River Company, states that the company calculate that by making such reservoirs they might obtain an additional 10 million gallons; and he believes the East London Company might do the same. 3972–80. 4020–1.

Mr. Greaves, engineer to the East London Waterworks, says that at one time in 1864 they took the whole volume of the river, after the New River had served themselves; there was nothing went by: they are now increasing their reservoir room to store partially the flood waters, which would give, say, five millions of gallons extra over 100 days' drought. He adds, however— 5131–9.

"I am of opinion that as the larger portion of London is dependent upon the Lee, it ought not to continue any longer dependent upon the Lee alone for its supply of water as to quantity. The caution that we had from the drought of 1864 was convincing. There is no room to doubt the question any longer." 5177.

Mr. Greaves's attention being directed to the propositions of the New River engineer above quoted, he says:

"I am not inclined to store so largely, or to depend upon storage to that extent, because I know that there are winters when it is quite likely those reservoirs might not be filled; the winter of 1858 went off without a single flood; we have charge of the floodgates ourselves on the river at Lee Bridge, which govern the whole flow, and in the winter of 1858 we did not draw a single gate; therefore where would the reservoirs be filled from in such a season? I consider the Lee alone not to be depended on, even for the East of London, and less so supposing the New River Company do an equal amount of work." 5178–9.

Mr. Mylne, whose plans for increase of the supply from the basin of the Lee we have noticed in Part II., conceives that by these plans the quantity derivable from this source might be raised by storage to 70,000,000.

The Rivers Pollution Commission, in their Report on the River Lee, 1867, say:

"With regard to the capability of the River Lee to meet the increasing demand for water supply in the eastern districts of London, it may be taken that no dependence can be placed upon an increase of the supply from the river without the construction of impounding reservoirs on a much larger scale than those now in existence."

144. We believe that we ought not to calculate on any material increase from this source, and that we may consider the quantity which the Lee valley can contribute to the supply of London as not more than 50 millions of gallons daily.

Subsidiary Supply from the Chalk.

145. We have referred fully in Part II. to the great store of water contained in the chalk round London.

6141. The only use now made of this for the metropolitan supply is by the Kent Company; who draw at present from it above seven millions of gallons daily, and appear to rely on an almost unlimited power of increase.

Many witnesses before us have testified in favour of this source, and the suggestions of Mr. Clutterbuck, Mr. Homersham, Mr. Barlow, and Mr. Meesom for utilizing it will be found noticed in Part II.

2520. Mr. Hawksley says that there are large districts of chalk where an immense quantity of
5083. water might be obtained, and that there is very fine water surrounding London in all directions, which only wants utilizing.

4045. Mr. Muir also speaks of the ease with which water is obtained in the chalk, and the abundant supply.

146. We do not agree with those who expect to get an almost unlimited increase of quantity of water by simply tapping the natural reservoirs in the chalk, for the supply to them must obviously be limited by the amount of rainfall. Moreover, as the water which penetrates into the reservoirs, raising the water line more or less above the level of the adjoining valleys, ultimately in greater part finds its way by springs into streams at the lower level of the district, any water drawn from the store by artificial means will most probably be at the expense of those streams.

If this be true, it follows that any water obtained by tapping the chalk reservoirs that feed either the River Lee or the Thames above Hampton, would only *pro tanto* diminish these streams, and would therefore be little or nothing gained to the general supply.

147. But there is, in the large area of chalk to the south and south-east of London, a reservoir which does not feed either of these streams, as its surplus waters find their way by innumerable springs into the Thames below London. From this reservoir, in all probability, large quantities might be drawn, and these quantities would be real additions to the supply.

We have no complete data as to the quantities which could be so obtained; but looking to the facts that the present few wells of the Kent Company are supplying above seven millions of gallons, and are said to be capable of supplying twice as much; that the Grays springs are said to be capable of supplying 10 millions; and that a small district near Gravesend has furnished an equal quantity; we believe we are very moderate in estimating the addition that might be made from this source by proper works at 30,000,000 gallons per day.

It is further probable that a considerable quantity of water, soft and of good quality, might be obtained in the neighbourhood of London by means of artesian wells in the *Lower Greensands;* but of this quantity there is no means of forming an estimate without further investigation.

Summary.

148. Combining now these several sources, we may estimate that if ever the metropolis should increase to such an extent as to render necessary such a large supply, and to justify the outlay for works necessary to obtain it, we may calculate on getting, from the basin of the Thames—

	Gallons per day.
From the main stream, supplemented by the aid of store reservoirs, say - - - - - -	220,000,000
From the Lee - - - - - - -	50,000,000
From the chalk to the south and south-east of London - -	30,000,000
or say, a total of - - - - -	300,000,000

Section II.

AS TO QUALITY.

149. We now proceed to consider the part of our subject which is probably the most important as well as the most difficult of the whole, namely, the *quality* of the water obtained or obtainable from the basin of the Thames.

The importance of this point is indisputable. It admits of no question that the metropolis ought to be supplied with water that is perfectly wholesome in quality. Water is a necessary of life; the consumers in a place like London have no power to choose their own source, but are at the mercy of the parties undertaking the supply; the health, often even the life, of the inhabitants is in the hands of these parties, and it is therefore a matter of paramount public interest that the manner in which they exercise this immense power should be jealously watched, and efficiently controlled. And if it could be clearly proved that either now, or in a proximate future, wholesome water could not be obtained from the Thames basin, the question of the abandonment of the source would demand prompt attention.

We have alluded to the difficulty of this question, because we have found not only that opinions are divided upon it, but that the elements which enter into its determination are of a very subtle character, and by no means admit of the satisfactory kind of treatment which we are in the habit of expecting from the modern advanced state of physical science. We have endeavoured to get the best information possible, from scientific men of the highest reputation, and who have had the best means of making themselves acquainted with the subject, and we have given their evidence its due weight; but we have also been obliged on some points to rely on other considerations in arriving at our decision.

150. It is nearly half a century ago that attention was first directed to the quality of the water supplied to London, and the Royal Commission of 1828, appointed in consequence of complaints on this head, reported to the effect that the water was naturally good, but was fouled by the admixture of foreign matters; and this led to the introduction of filtration, by which the quality was much improved.

The Board of Health report of 1850 pointed out the impure state of the Thames within the tideway, but objected generally to the Thames water, even in its purest state. The Chemical Commission of 1851 reported fully on the subject, in terms we shall have to quote hereafter; and in 1852 a great improvement was effected by the passing of the Metropolis Water Act, which compelled the companies to take their water from a point above the tideway, to filter it effectually, and to preserve it in covered reservoirs.

In 1866 and 1868, in consequence of the reports of the Royal Commission on the Pollution of Rivers, Acts were passed compelling towns and villages within certain limits to dispose of their sewage without polluting the Thames and the Lee; but the effects of these Acts have not yet been proved.

151. We may most conveniently divide this part of our inquiry into two heads:—

A. What is the evidence as to the present quality of the water in the Thames and its tributaries?

B. What are the influences likely to affect its quality for the future?

A.—ON THE PRESENT QUALITY OF THE WATER IN THE THAMES AND ITS TRIBUTARIES.

152. We have taken a large amount of evidence, tending to illustrate this question, from persons of the highest authority, and whose opinions on the various points involved in the inquiry we shall quote in their proper places. But as, on several previous occasions, the waters of the Thames have been analysed and reported on, we have deemed it right also to refer to such of these analyses as appear to us most authoritative and trustworthy. And we may mention the following as deserving of special attention:—

The Chemical Commission of 1851 gave a full analysis of the waters then supplied to London, which we have reprinted in Appendix A F.

In 1856, after the water companies had removed their sources of supply from the Thames to points above the tideway, in accordance with the Act of 1852, a further analysis was made on behalf of the Government, by Messrs. Hofmann and Blyth. We have reprinted portions of this analysis in Appendix B G.

On the inquiry by the House of Commons Committee in 1867, analyses were put in evidence, made by Dr. Letheby, Dr. Odling, and Professor Abel; these we have reprinted in Appendix A G.

The same chemists have also made for the London water companies a later analysis, which has been sent to us, and which we have printed in Appendix A H.

Another set of analyses that deserve special attention are those published monthly by the Registrar General. It appears that after the cholera epidemics of 1849 and 1854 the attention of this department was drawn to the water supply of the metropolis, and an arrangement was instituted by which a monthly analysis of the waters was made, in the first instance by Dr. Robert Dundas Thompson, then by Professor Hofmann, and latterly by Dr. Frankland. The results are published once a month in the Registrar General's returns of the health of the metropolis, and a summary is made at the end of each year. We give some examples of these documents in Appendix A J.

153. The analyses above referred to all apply to waters actually delivered in London by the various companies, and taken from their ordinary sources of supply; but we found that the extended nature of our inquiry rendered these data insufficient. It was our business to report on the water of the Thames basin generally, and therefore it was necessary that our information should not be limited to one point, but that we should know something of the general quality of the water in different parts of the basin, and should endeavour in the first place to ascertain its natural condition when in its pristine state of purity, and then to trace, as far as we could, the various influences it was subject to during its flow. For this purpose, with the sanction of Your Majesty's Treasury, we determined to have samples of water collected from various parts of the basin and analysed in the same manner as in the cases of the Welsh and Cumberland districts. The selection of the samples was entrusted, as before, to Mr. Pole, whose report thereon will be found in Appendix O, and the analyses of the waters by Drs. Frankland and Odling are given in Appendices A X, 1 and 2.

154. We shall, in treating of the chemical quality of the waters, adopt the usual plan of making a broad distinction between the *mineral or inorganic contents*, such as metallic and earthy salts, which in the case of river waters are found present in their first sources; and the *organic contents*, which become added to the waters by accidental circumstances during their flow.

155. The mineral or inorganic contents of the Thames water supplied by the companies from Hampton appear to amount usually to from 15 to 20 grains per imperial gallon of water, of which more than one half is carbonate of lime, and the rest sulphate of lime with salts of magnesia, soda, potash, and silica, and traces of alumina and iron.

The waters of the Lee valley, as supplied by the New River and East London companies, differ little from those of the Thames; but those of the Kent Company being drawn directly from the chalk, contain a considerably larger quantity of the salts of lime.

156. The point, connected with these mineral contents, which is of the main importance in our present inquiry, is their influence (chiefly caused by the presence of lime) in giving to the water the peculiar quality called *hardness*. In the investigations that have taken place from time to time on the water supply of the metropolis, the hardness of the water has always been a prominent topic of discussion, often involving elaborate general comparisons between the eligibility of hard and soft water respectively for the supply of towns. It is, therefore, necessary that we should give a summary of the information we have obtained on this point, and the conclusions at which we have arrived thereon.

On the Hardness of the Thames Water.

157. Owing to the solvent power of water, all waters percolating through or flowing on the surface of the earth take up more or less mineral matter, consisting in almost all cases of carbonate of lime as the essential ingredient, and of a few other salts as subordinate ones. When these mineral matters are in excess the waters are called mineral waters; but in moderation, say 15 to 30 grains to the gallon of 70,000 grains, they are present in almost all river waters.

Water charged with salts of lime has the property of decomposing soap to a certain extent, by the combination of the lime with the alkali, and this is what is meant by the popular description of the water being "hard." Soft water makes a lather freely, but

hard water curdles a portion of the soap, and requires consequently more of it for the purpose of washing.

158. The first attempt to investigate the hardness of water in a way combining scientific research with practical utility, was by the late Dr. Clark of Aberdeen, who shortly before his death wrote to our chairman the letter on the subject which we have printed in Appendix G. His attention was directed about thirty years ago to the hardness of the London waters, and in March 1840 he took out a patent for a mode of softening them. This invention has proved to be a practicable process of much utility, and we shall have occasion to refer to it hereafter; it is important to our present object that in his patent Dr. Clark described a mode by which the hardness of water could be *defined* with great exactness. He first formed a series of artificial waters of several grades of hardness, each containing a known proportion of bicarbonate of lime; and when any unknown water was to be tried he compared its effect on soap, by an ingenious process, with these as standards, and so at once obtained an accurate measure of its hardness. He proposed to designate the hardness of water by the *number of grains of bicarbonate of lime contained in one imperial gallon* (or 70,000 grains) of a standard water producing the same curdling effect. This process is known as "Dr. Clark's test," the number of grains being called "degrees." It is exceedingly easy of application, even by persons without any chemical experience; it is very definite and accurate; and it has been very generally approved and adopted by chemists treating of the subject. The Registrar General's reports, however, give the number of grains of carbonate of lime in 100,000 grains instead of 70,000, so that to compare these degrees of hardness with those usually adopted, they must be reduced in the ratio of 10 to 7.

159. The water of the River Thames, supplied as it is in great part by springs from chalk and oolitic limestone, is naturally somewhat hard. It is, however, well known that flowing water tends to part with a portion of the carbonate of lime it holds in solution, and therefore, whatever may be the hardness of the water as it issues from the chalk or any calcareous strata, after a flow of some miles it falls to a nearly uniform standard, varying from about 12 to 15 degrees in the imperial gallon.

The Chemical Commission of 1851 gave the hardness of the metropolitan waters as follows:—

"The hardness was remarkably uniform in the water of the eight principal metropolitan water companies.

"The degrees of hardness, by Clark's soap test, of the waters of the eight principal London companies, observed on the 29th, 30th, and 31st of January, were as follows:—

"From other sources than the Thames.	New River	14°·9
	East London	15°·0
	Kent*	16°·0
"From the Thames.	Grand Junction	14°·0
	West Middlesex	14°·6
	Vauxhall and Southwark	15°·0
	Chelsea	14°·4
	Lambeth	14°·2
	Lambeth (from Thames Ditton, March 8)	14°·2

"The variation observed in this property is from 14° to 16°; or if the Kent water be excepted, from 14° to 15°, or one degree only. It appears also, from observations made at different seasons, that this range is not considerably exceeded at any period of the year, except during floods, when the hardness of Thames water may fall to eight or nine degrees."

The analyses by Drs. Letheby, Odling, and Abel of waters taken between December 1866 and February 1867 give the hardness from 13 to 14½ degrees; that of waters taken in May, June, and July 1868 is somewhat less. They say,— App. A G. App. A H.

"On reference to Table No. 1, it will be observed that the hardness of the water supplied by the Thames companies ranges from 11·3° to 12·5°—that from the New River being 11·9°; while the water from the East London Company has a hardness of 11·7°; and that of the Kent Company a hardness of 17·6°.

"After boiling for fifteen minutes, the hardness of the water from the Thames companies is reduced to between 2·4° and 3·5°; the New River water to 2·3°; the East London water to 2·6°; and the Kent Company's water to 6°.

"On comparing these results with the return of analyses made by us in the winter of 1866–7 (in reference to the Metropolis Water Inquiry, conducted by a Committee of the House of Commons in 1867), it will be observed that in all instances excepting that of the Kent Company's water (derived solely from deep wells), the hardness is less than that of the water collected during the winter season, a result which is in accordance with previous experience regarding the fluctuations in the composition of river water at different seasons."

The analyses of the Registrar General, when corrected on account of their unusual form, give a variation in 1847 from 11¼ to 16 degrees, omitting the Kent water, which varied from about 15 to 20 degrees.

* At this time the Kent Company took water from the river Ravensbourne.

App. A X. The analyses made for ourselves by Drs. Frankland and Odling show the following results when reduced to Dr. Clark's scale:—

	Hardness according to Dr. Clark's scale.	
	Before boiling.	After boiling.
Head Waters.		
Oolite Springs	15·3	3·4
Main Stream of the Thames.		
At Lechlade	15·3	3·6
Above Oxford	12·7	5·4
A little below Oxford	13·4	5·7
Seven miles below Oxford	15·4	6·3
Above Reading	14·7	5·7
A little below Reading	12·7	4·0
Five miles below Reading	14·0	5·3
At Medmenham	13·6	5·3
Above Windsor	15·5	5·2
Below Windsor sewer	15·7	5·2
Three miles below Windsor	14·6	7·4
At Hampton	14·0	3·0
Tributaries.		
Cherwell	15·9	3·6
Thame	17·9	4·5
Chalk Spring, Watford	17·3	2·6
Kennet above Hungerford	15·2	2·5
„ „ Reading	13·7	1·7
Bagshot Sands	1·0	1·0
Wey	5·8	5·6
Mole	11·3	3·1
Outlying Waters.		
Lee and Mimram mixed	14·0	1·5
Amwell Well	14·7	4·1
Caterham Well	16·4	6·3
Croydon Well	15·4	6·4
Wandle at Mitcham	14·8	6·8

160. The hardness of the London water does not seem prominently to have attracted attention, as forming any serious objection to the source, till the appearance of the Board of Health Report of 1850. Indeed, on the contrary, the more general desire seems to have been, when the Thames was found fault with, to resort to the chalk springs, whose water was harder still. The Board of Health, however, were of a different opinion, and laid so much stress on the supposed evils of the hardness of the water as to recommend the abandonment of the Thames almost on this ground alone.

161. The effects of hardness have been discussed in regard to the use of the water—

a. For drinking.
b. For culinary use.
c. For washing and for manufacturing purposes.

We propose to give a summary of the evidence we have been able to collect on each of these points: but before doing this we may quote a few explanatory observations, by the Chemical Committee of 1851, who devoted much attention to this branch of the subject, and to whose opinions on it we attach great value.

162. They say—

"It may be useful to distinguish the quality known as the 'hardness' of water according as it is of a temporary or permanent character. Perfectly pure or soft water, when exposed to contact with chalk (carbonate of lime) is capable of dissolving only a very minute quantity of that substance; one gallon of water, in weight equal to 70,000 grains, taking up no more than two grains of carbonate of lime. This earthy impregnation is said to give the water two degrees of hardness. But waters are often found containing a much larger quantity of carbonate of lime, such as 12, 16, or even 20 grains and upwards in the gallon. In such cases the true solvent of the carbonate of lime, or at least of the excess above two grains, is carbonic acid gas, which is found to some extent in all natural waters. But this gas may be driven off by boiling the water, and the whole carbonate of lime then precipitates in consequence, or falls out of the water, with the

exception of the two grains which are held in solution by the water itself. The gas-dissolved carbonate of lime gives therefore temporary hardness curable by boiling the water. An artificially prepared hard water, containing 13½ grains of carbonate of lime to the gallon, was observed to decrease from 13·5 to 11·2 degrees of hardness, merely by heating it in a kettle to the boiling point. Boiling for five minutes reduced the hardness to 6·3 degrees, 15 minutes to 4·4 degrees, 30 minutes to 2·6 degrees, and one hour to 2·4 degrees. The softening effect of boiling does not therefore appear all at once, but the greatest proportional effect is certainly produced by the first five minutes' boiling. The West Middlesex and New River waters were both found to soften by boiling, very much in the same manner as the preceding pure chalk water, except that the ultimate hardness of the two waters specified was somewhat higher. By an hour's boiling the West Middlesex fell from 14·6 to 5·5 degrees, and the New River from 14·7 to 4·1 degrees.

"Other salts of lime, such as sulphate of lime, are generally dissolved in water without the intervention of carbonic acid gas, and therefore remain in solution although the water is boiled, imparting hardness.

"The carbonate of lime in water decomposes about 10 times its weight of soap in washing (more exactly 8·8 white curd soap and 10·7 common yellow soap), and other salts of lime act injuriously upon soap, in proportion to the lime they contain; the soluble soap containing soda being converted into an insoluble and useless compound containing lime. The water is then deprived of lime or softened at the expense of the soap. The lime in 100 gallons of Thames or of New River water thus occasions the destruction of about 34 ounces of soap, before any portion of it becomes available as a detergent."

a. Effects of Hardness of Water for Drinking Purposes.

163. The Board of Health collected evidence on this point, and expressed an opinion "that the presence of lime and other mineral matter deteriorates the wholesomeness and "value of waters for the purposes of drinking."

The Chemical Commission of 1851 held different views. Their Report says:—

"When in good condition, the Thames water possesses the peculiar and agreeable brightness of chalk waters, arising from the entire absence of colour, combined also usually with good aëration.

"The Thames water may be described to be, in circumstances not unfavourable to purity and coolness, a palatable water. The amount and nature of its saline constituents probably contribute to its general acceptability as a beverage.

"It may be safely stated, that no sufficient grounds exist for believing that the mineral contents of the water supplied to London are injurious to health. No reasonable doubt indeed can be entertained of its salubrity. The shallow well waters of London vary from 32 to 80 degrees of hardness, yet these waters have never been pronounced unwholesome.* An aërated water is manufactured and safely consumed to some extent which contains 92 grains of carbonate of lime to the gallon, instead of 12 or 14 grains, as in Thames water. The portion of lime and magnesian salts in the water drunk must indeed be greatly exceeded in general by the quantity of the same salts which enters the system in solid food. The only observations, from which an interference of the lime in water, in deranging the processes of digestion and assimilation in susceptible constitutions, has been conjecturally inferred, have been made upon waters containing much sulphate of lime and magnesia, as the Brighton shallow well water, or the hard selenitic water of the New Red Sandstone, and have no force as applied to the Thames and its kindred waters, as the earths exist in these principally in the form of carbonate."

164. Mr. Bateman expresses his firm conviction that soft water is very much more wholesome than hard water, but he remarks at some length on the difficulty of finding any tests by which the effects can be truly ascertained. 6680–6700.

Mr. Hawksley says on this point: 2600.

"I imagine there are quite as many fine-raced people living in hard water districts as there are living in soft water districts. I am well acquainted with districts of both characters, and I may say that quite four-fifths of the whole surface of the globe yields hard water—in fact, the cretaceous strata and the other lime formations occupy a large portion, from which alone hard water can be obtained. I think these extend quite to four-fifths of the earth's surface."

Mr. Beardmore states that his experience leads him to consider hard water is preferable for drinking purposes, and Mr. McClean agrees in this opinion. 3381–7. 5641.

Mr. Rawlinson thinks the evidence conflicting as as to what is the best water for health, and believes that change either from hard to soft water, or *vice versâ*, is prejudicial. He considers that by far the greater quantity of water drunk in England is hard water, all above six degrees of hardness being so designated. 1363–80.

Mr. Way thinks the question of hardness would have a reference more to habit than anything else. It is exceedingly doubtful whether water of two or three degrees of hardness is more healthy, because people are in the habit of drinking waters of 17 or 18 degrees of hardness without any apparent injury to health. The waters which are the brightest and most liked are the hard waters—the chalk waters. There is no reason to believe chalk water injurious, except perhaps in some special instances. As to the question of health, he does not attach importance to the hardness, either one way or other, if it is in moderation. 1457–61.

Mr. Duncan mentions the opinion of the medical officer of Liverpool, that a change from hard to soft water was prejudicial. 2185–97.

* The objection more recently brought against the shallow well water in London, is on account of its pollution by the infiltration of organic matters from the soil, and not from the natural mineral contents or hardness.

3934. Dr. Letheby considers a moderately hard water best for drinking purposes and for the general supply of cities. He illustrates this opinion by reference to the supplies of Paris and Vienna. A large proportion of the earth's surface consists of calcareous districts, supplying hard water. He is not aware of any instance of moderately hard water producing gravel or surgical affections.

2646-2719. Dr. Lyon Playfair gives evidence as follows:

As a sanitary question, if the water is otherwise pure, I do not think that mere hardness is of much importance as to health; in extreme cases I would consider a hard water injurious to health, but in ordinary cases, such as the Thames water, I do not think it injurious to health, if there are no other impurities in the water than the mere differences in the amount of carbonate of lime.

In some cases hard water might prove injurious, as in calculous affections and in dyspepsia, still, generally, a tolerably hard water may be taken without much inconvenience; but water of 20 degrees of hardness is very hard water, and I would much prefer, even for purposes of health, that it should be softer.

2661. Taking the water which comes from the springs in the chalk, do you consider that water generally to be prejudicial to health?—No, not prejudicial to health, except in the circumstances which I have mentioned.

2691. Are you aware of any experiments which have been made with regard to the advantages of the use of either hard water or soft water for drinking purposes?—I can only rely upon the experiences of large towns where they have been supplied with hard water and the supply has been suddenly changed to soft water; of course I do not know of the reverse instances where soft water has been suddenly changed to hard, but in the former cases I never saw any deterioration of health.

2692. Do the returns of the mortality of the towns now supplied with soft water show any improvement in consequence of the use of soft water?—I might mention such towns as Liverpool, for instance, where there has been a very large improvement in the health, but the introduction of soft water was only one of many hygienic improvements which took place at the same time; therefore, the proportion which should be attributed to that is difficult to distinguish from the others.

2693. That probably would be the case in almost all instances where a new water supply has been introduced?—It is; for a new and enlarged supply of water generally arises when a population has become awakened to the necessity of hygienic improvements generally.

3124-3218. Dr. Parkes's evidence on this subject is as follows:

With regard to the effect upon health of the use of hard waters, distinguishing between the carbonate of lime water and the sulphate of lime, and sulphate of magnesian waters, the carbonate of lime waters appear in some cases certainly to produce some effect upon health, for instance, dyspepsia, and they do not agree with some class of persons, whereas to others they appear to be quite harmless. There is a large population living upon chalk water, and we cannot trace any very decided effect upon their health in the production of any class of disease—calculus or anything of that kind, but at the same time persons do sometimes suffer from indigestion.

3125. What degree of hardness would, in your judgment, be a safe water, taking an average constitution; some people will live in spite of difficulties; their resistive force being such that nothing seems to affect them, but my question has reference to an average constitution?—I do not think with regard to pure chalk water that there is any evidence that a moderate amount of carbonate of lime in the water does any harm, certainly not on the large scale; in some individuals it produces indigestion.

3126. Would 16 or 20 degrees of hardness be prejudicial?—I think that that degree of hardness would be certainly prejudicial. I think that very probably it might disagree with a great many persons; but supposing it reached to 8 or 10 or 12 degrees of hardness from carbonate of lime, it might be considered probably good water as far as that was concerned, but I should draw a marked distinction between that and the hardness arising from sulphate of lime, or sulphate of magnesia, or chloride of calcium, which would certainly disagree in much smaller quantities, so that the goodness of water for drinking purposes I would estimate according to its permanent hardness rather than according to its temporary hardness.

3134. But supposing the water was equal in purity and free from organic matter, does the question of simple hardness or softness enter into the consideration of those whose special duty it is to care for the troops with regard to the kind of water that they should use?—In all cases we would prefer a soft water if it were possible to obtain it; and if the water were permanently hard, to a large extent that water would be reported upon unfavourably, and better water as regards that property would be procured if it were possible.

3137. Speaking generally, you are of opinion that the mere presence of carbonate of lime of 15 degrees of hardness would not be injurious to health?—With 15 or 16 degrees of carbonate of lime hardness I should say that it would be hard water, and with some persons it would disagree and produce dyspepsia. I think it should not exceed 10 or 12 degrees if possible. At the same time I should wish to state that one would prefer water free from that even, if it were possible to get it.

3201. The greater part of the troops I presume in this country are located in districts where the water is of a moderate degree of hardness; for instance, Dover, Portsmouth, Southampton, Plymouth, and the greater part of Ireland?—Yes, and at Chatham. At Southampton we have no troops, and at Aldershot the troops are upon soft water. At Chichester the water is hard, and at Colchester it is hard. For the most part they are chalk waters.

3202. Have you known instances of any ill effects from the use of such waters?—Not of the good chalk waters.

3203. Have you known any instances where troops have been located in districts where they have been using water of a moderate degree of hardness, and have suffered when they have been removed to a district where the water was soft?—I have never seen any reports of that kind.

3212. Are you aware whether a certain quantity of carbonateof lime may not in many cases be rather beneficial than otherwise to health?—I think that is again very doubtful. The fact is, that almost all kinds of food contain enough lime for the supply of the body, and the quantity of carbonate of lime supplied in water might no doubt be applied to the wants of the system, but I can hardly think that it would be necessary, that is to say, I do not think it should be an argument for the supply of chalk water that lime is thereby supplied.

3217. I see that one disorder which you mention is calculi; have you been able to trace that back to the use of water?—In Germany especially there is a very strong opinion in certain parts that the phosphate of lime calculi and calculi generally are more common in districts where the inhabitants use very hard waters, but in this country the evidence is so far negative; we have not many districts supplied with limestone

waters or the magnesian limestone waters; most of our lime waters are chalk waters, and so far, I think, in this country there is no evidence of there being a greater amount of calculi than in other districts not supplied with this water, but in Germany and, perhaps, in France the evidence is stronger that the use of some of the lime waters may have an influence in the production of some of the calculi.

3218. Would that be in the case of water of an ordinary degree of hardness, or of an excessive degree of hardness arising from the chalk or from the presence of sulphates?—I believe especially from the large amount of hardness arising in most cases from the mixture of chalk and of sulphates, at least it is so in most of those waters.

Mr. Simon says:—

2777–2835.

2777. Has your attention been directed to the quality of the water in London for drinking purposes, as to the effect upon the health of the inhabitants, as compared with water of a softer and purer character?—I have no evidence upon that subject. I think that, practically, the only very important sanitary question as regards the quality of the water supply to London is the question of organic admixture. I do not think that the question of a few grains of lime in a gallon of water can be regarded as a very important sanitary question.

2778. Then, in your judgment, the presence of lime, or two or three degrees of hardness in the water, would not be a matter of much consideration, supposing the water were free from organic impurities?—Quite so, as regards the public health.

2779. For drinking purposes, probably a little hardness in the water would add to its life and pleasantness to the taste?—I would not quite say that; I have found soft waters, or at all events, hard water artificially softened, very agreeable.

As regards drinking purposes, I am not sure of any important difference, but am inclined to prefer the soft water.

2791. Do you know of any experiments which have been made with regard to the use of soft water and hard water upon health?—If by hard water is meant such water as we have in London, I am not aware of any facts of the smallest value showing difference of effect between such water and soft water.

2792. It has been stated that there are certain classes of diseases more prevalent in districts where hard water is used than in others, for example, diseases of the bladder and the stone; can you give us any evidence on that point?—I do not think there is any evidence that is worth a rush upon that subject.

2793. That evidence which was given by Dr. Prout some years ago you do not attach much importance to?—I do not remember the exact language of Dr. Prout upon the subject, nor know whether he professed to argue from any large field of observation; but I believe that no statistics of value exist in proof of such an assertion.

2823. Although it is a hard water, in some cases to even 18 or 20 degrees, yet it would not be in your mind, in a sanitary point of view, objectionable to use that water?—It would not make it unwholesome water, so far as I know, for drinking, but there would remain of course the economical question.

2824. Therefore we may assume that the question, as between the existing water in the Thames basin and pure soft water, would be practically reduced to its economical results for the purposes of washing and culinary purposes and domestic use?—Yes.

2825. As far as the simple sanitary question goes, you see no objection at all to it?—No.

As regards health my bias is in favour of soft water, but I cannot say that I think the case established against hard water (*i.e.*, against hard water of such comparatively few degrees of chalk hardness or carbonate of lime hardness as you have in the London waters) that it acts injuriously on health. It is different, of course, when you come to certain other hardnesses of water; but I do not think that the hardness, for instance, of the New River Company's water can be considered detrimental to health.

Dr. Frankland says:—

6259. 7777. 352–6.

6259. You have spoken as to the properties of the London water with regard to health; what is your opinion as to the effect upon health as between hard water and soft water?—My opinion is that there is no difference.

6277. For drinking water you say you attach no importance to that difference of degree of hardness?—Not as regards its effect upon health, but I attach great importance to it in the use of water for cleansing purposes.

6352. Some difference exists, does there not, in the opinion entertained by medical men and chemists with regard to the effect on health of soft and hard waters?—There has been some difference of opinion on the subject, but I think the general impression now is that there is not much to be said upon that point, that they are equally good as regards their effect upon health.

6355. Have you any reason to suppose that hard water as drinking water might exercise, not any direct influence in the way of supplying carbonate of lime to the body, but in taking away less organic or mineral matter from the body than soft water?—I have never considered the subject from that point of view, I confess; but the quantity of matter dissolved in the hardest water ever used for drinking purposes is such a very small fraction of the total solvent power of the water, that I should not imagine that there could be any substantial difference between the two kinds of water in that respect.

6356. Have there been any experiments upon that point?—No, not that I know of.

Dr. Odling says:—

7054–8.

6439. On the score of health do you make any distinction between soft and hard water?—I do not think there are any facts which enable one to give a positive opinion. Some gentlemen who have considered the subject entertain very strong opinions both ways; but I do not know any facts upon which one can speak positively.

6478. What is your opinion with regard to the presence of carbonate of lime?—For mere drinking purposes I do not consider it a matter of any disadvantage at all.

Sir Benjamin Brodie's evidence is as follows:—

7023. Have you any reason to suppose that the use of soft or hard water as a drinking water produces any difference of effect upon health?—I cannot say I have reason to think so.

7024. Have you any reason to suppose that the health of a district is independent of that?—I have no reason to think it to be dependent upon it.

7025. Is there not a want of direct experiment upon that subject?—Oxford is a place where the spring water is extremely hard, and injuriously hard for every purpose, but I never heard that it had been made out

that Oxford was liable to any particular class of complaint from that reason. If it were so, I think it would have been discovered; but perhaps some physician from the infirmary might tell you to the contrary.

Dr. Miller thinks any precise observations on this point are difficult to obtain, but he thinks, so far as observation goes, it is a matter of indifference whether it is hard or soft water. He adds:—

"It depends upon the quality of the hardness. Chalk waters, I consider, are waters which are perfectly wholesome, but waters which have a similar degree of hardness from sulphate of lime there appears to be some reason to believe are found occasionally to disagree with persons. Still there are waters which are supplied to large populations containing sulphate of lime, and very hard sulphate of lime waters. For instance, the population of Wolverhampton and Birmingham are supplied with water of this kind. It is certainly objectionable, but what I was going to say was that the evidence in that case is that there is no sensible injury to health directly traceable to the water as far as observations go. I believe, generally speaking, the impression is that the hardness caused by sulphates of lime and magnesia is more likely to produce certain slight derangements than the use of chalk waters of a similar degree of hardness. I should not think there was the slightest reason to suppose that any injury would result from such water. From long habit I should certainly prefer hard water for drinking purposes to soft water."

7095. Are not a very large proportion of the waters consumed in this country, or in any other country, flowing as they do over calcareous formations principally, hard waters?—Yes, they are.

7096. And the proportion of soft water used is comparatively small?—The Scotch waters are many of them very soft, and some of the waters in Cumberland are soft. Whitehaven and several large towns are supplied with soft water now, but in the south of the island the water supply is generally hard.

7097. Have you had occasion to notice whether the change from one water to the other produces any ill effects upon the health of the inhabitants?—I have no observations upon that point.

"Have you formed any opinion yourself as to the comparative value of a supply of water of a moderate degree of hardness to a town, or of a soft water supply?—I should say that for drinking purposes a hard water is preferable, and it is liable to a less frequent change than a soft water. The principal objection which appears to me to arise in the case of soft water is that it is liable to peaty discolouration, which makes it at times very disagreeable for drinking purposes, and it is also more liable to absorb organic impurities. I should prefer, merely looking at it as an abstract question, water of a moderate degree of hardness for drinking. I must say that for domestic use soft water is preferable on account of its economy, but for dietetic purposes I think hard water has the preference.

"Do you know of any experiments bearing directly upon that question with regard to the effect upon health?—No, I have no observations upon that point. Having always lived in a hard water district I certainly prefer it for drinking purposes, but I believe persons who live in soft water districts are equally favourable to the use of soft water."

7124. Dr. Angus Smith gives evidence as follows:—

7260. Have you been able to form any opinion as to the effect upon health of the use of soft water or hard water?—I do not think there is good evidence upon that point. I have heard of horses losing their appearance when they used hard water, and of persons of my own acquaintance who got indigestion by coming into hard water districts; but then I must say that those cases are somewhat balanced by people being rather disagreeably affected on going to soft water districts, and especially some of the hilly districts of the north.

7261. That depends a good deal, I presume, upon the previous habits of people?—Yes. I do not think that there is a great deal of evidence on either point. I do not think it is fair, in fact, to take the appearance of the population as any criterion. If we did so, we might find some arguments in favour of soft water. I should think that the tallest people in Great Britain are to be met in soft water districts; for instance, in Cumberland and, probably, in Aberdeen; I may say that the tallest people I have seen in Great Britain are in Aberdeen, which is a very soft water district.

7264. Are not soft water districts generally mountain districts, where they have the purest air as well as pure water?—Yes; I believe, however, it is quite possible for the blood to take up matter which is inorganic dissolved in water.

165. From the above evidence, at any rate, there is no reason whatever to suppose that the hardness of the Thames water would be in the least degree prejudicial to health.

Some eminent chemists have contended that a moderate quantity of carbonate of lime is not only harmless, but that it is actually useful in supplying material for the bones of men and animals. Considering, however, the much larger quantities of carbonate of lime taken in our solid food, such an additional source of supply would seem to be unnecessary. Judging in fact from the condition of the inhabitants of soft water districts well supplied with a variety of food, it is evidently perfectly immaterial, although it may be otherwise in districts short of carbonate of lime, and when the local produce suffers from the same deficiency as the water. Still it remains to be shown whether when large quantities of water are drunk, those waters which contain the smallest quantities of mineral ingredients may not dissolve and take away more from the body than harder waters, and whether there should be any cause for preference on these grounds.

It may also be a question whether, from the better keeping qualities of waters of a moderate degree of hardness, from their general better aëration and greater freshness, and from their lesser solvent power, such waters are not the best for drinking purposes. Perfectly pure water does not exist in nature. All spring and river waters contain more or less mineral ingredients, and it is only in limited mountain districts, where hard and non-calcareous rocks prevail, that water is found approaching a nearer standard of purity. That the use of these purer waters is more conducive to health is without proof; there is,

however, a great want of exact evidence on the subject of the dietetic value of soft and hard waters.

b. For Culinary Purposes.

166. Another of the objections of the Board of Health to the Thames water was that, by reason of its hardness, it was unfit for the preparation of tea, by occasioning waste, and for all culinary processes by diminishing their efficiency and increasing their expense.

167. The Chemical Commission of 1851 remark on this point as follows:—

"The hardness of the metropolitan water supply, which is due to its mineral constituents, may be considered as the same whether derived from the Thames or the Lee, and amounts on an average to about 14 degrees. Although this degree of hardness is considerable and highly objectionable, still it is exceeded by the hardness of pure chalk waters, such as are supplied by water companies to the towns of Gravesend, Dover, and Brighton, and which may be estimated at from 18 to 20 degrees. The deposit which Thames water gives rise to in boilers is also friable and less coherent than the stony deposit from selenitic waters; and means exist, such as the use of sal ammoniac, for entirely preventing the occurrence, in steam boilers, of deposit from chalk but not from selenitic waters.

"The hardness of the London water is also of the least objectionable kind, being chiefly, as has been already stated, temporary hardness, which is removed by boiling. The whole 14 degrees of hardness can be ascribed only to that portion of the water which is used cold. To ascertain the average state of hardness of heated water, portions of water were drawn on six different occasions from the fixed boiler of a kitchen range supplied with New River water; the hardness was found to be 5·4, 4·9, 4·1, 4·1, 4·9, and 5·3 degrees, of which the mean is 4·8 degrees. The hardness of London water, as it is commonly used after boiling, appears, therefore, to be about five degrees, while without heating it amounts to 14 degrees. The distinction between permanent and temporary hardness was illustrated to us at Greenwich, where the brewer described the deep well-water of the Hospital (which is only occasionally pumped up) as a soft water, although its hardness is 21 degrees; but it is only used by him for mashing after being boiled, when, being a pure chalk water, its hardness is reduced to about four degrees. The importance of this distinction was likewise shown, though in another manner, at Whitehaven, where a great and apparently disproportionate advantage has been experienced, from a change in the town supply, from a water which we found to be of 6·7 degrees of hardness to another water of 1·4 degrees. The hardness of the former water, however, although not great in amount, proved to be of the permanent description, as after an hour's boiling the water of the old supply was still of 6·4 degrees, that is, harder than even the Thames water is after boiling. The hardness of the former town supply in Lancashire, although often inconsiderable, was generally of the same permanent character as the old Whitehaven supply.

"The hardness of water forms an objection to its use, both in cooking and washing, but the force of the objection to the Thames water for culinary purposes is much diminished by the large amount to which that water is softened by boiling. Tea is prepared in London with water which, it appears, is practically of only five degrees of hardness. It appears impossible to obtain any standard or test, by which the strength of an infusion of tea can be expressed in numbers, or to find any means of judging of its quality more precise than the indications of taste. On carefully comparing infusions, prepared as for family use, of an equal quantity of tea in the New River water before described, which averaged about five degrees of hardness, and in water of 2·4 degrees only, the observation made on several different occasions was, that the inequality in strength and flavour of the two infusions was altogether insensible to some palates. But an increase in the bitterness was more generally remarked in the soft water infusion, without enhancement of flavour. Where a preference was expressed it was in favour of the quality of the hard water infusion, but the difference between the two infusions was not considered material by anyone.

"Hard water is disadvantageous for making tea chiefly, it appears, by requiring the heat to be longer maintained in preparing the infusion. Tea is habitually made of excellent quality and with economy, in some families, by means of spring water of a high degree of permanent hardness; but then the infusion is continued for half an hour, and the temperature maintained near the boiling point during that period. The tea for the Greenwich pensioners is infused in a large copper, surrounded by a steam case, with water from a well in the superficial gravel, of 24 degrees of hardness, of which 18·6 degrees are permanent. But in the private residences adjoining it is found necessary to use carbonate of soda for softening, with the same water, in the absence of the efficient means of infusing described. Where any great loss of strength of the tea infusion has been observed, in passing from a soft to a harder water, it may be probably referred to the circumstance that the mode of infusing has not been properly adapted to the hard water. The use of hard water must on this account be attended with a frequent waste of tea. The rapid process of infusion generally employed in London indicates the use of a comparatively soft water. The water to which M. Soyer gave a preference for tea-making, even over distilled water, in experiments reported to the General Board of Health, was the London deep-well water. This is usually softer than Thames water after boiling, and contains, in addition, a sensible quantity of carbonate of soda, to which its superiority is probably due in part. The water of the Trafalgar Square deep well has an original hardness of 5·4 degrees, which is reduced to 1·1 degree by boiling. No great objection can be taken to the use of the London water for other culinary purposes. The presence of much sulphate of lime in water makes it unsuitable for cooking vegetables, owing to the tendency of that salt to form an insoluble compound with their legumine; but this effect is insensible with Thames water."

168. Mr. Bateman refers to the evidence of M. Soyer before the Board of Health, substantiating, as he considers, an economy in cooking. 55–63.

Mr. Hawksley coincides in opinion with the Chemical Commission, and refers to the fact that the London water, and all chalk waters, are very soft after they are boiled; adding that for manufacturing and many other purposes water is boiled, and also for many domestic purposes. 2511.

Mr. Rawlinson considers there would be great economy in household purposes by the use of soft water. 1345–6.

1457–61. Mr. Way also thinks soft water would be economical for cooking purposes. But he adds:—

"Hard water makes better tea than soft, although this is contrary to the general impression. The truth is that soft water makes a darker coloured tea, and dissolves a quantity of bitter extract, which makes the tea strong; but to a refined taste hard water gives much the best flavour, as it leaves the disagreeable matter undissolved."

6267–8. Dr. Frankland, while preferring generally soft water, states that boiling the London water causes it to lose more than half its hardness. As to making tea, he says: —

6359–61. "It is generally held that soft waters make better tea than hard waters, but I do not think that, as an abstract proposition, that is the case. I think that both waters are capable of making equally good tea, but the difference depends upon the length of time that the brewing is conducted. A hard water requires to be longer in contact with the tea at an elevated temperature than a soft water does, and there may be some influence of that kind in dyeing, so that by prolonging the operation you get an equally good result, and it may be perhaps in some cases a better result from hard water than you can get from soft water.

"What is the case with regard to brewing?—With regard to brewing, the case I think is this, that where you want to brew a pale ale it is absolutely necessary to have hard water, and not merely hard water, but water that is permanently hard, that is, water which contains sulphate of lime; but in brewing any other kind of ale, where the colour is not of importance, probably soft water is best to be used as extracting a greater amount of matter from the malt.

"In brewing tea with the London water, which I suppose would probably be softened down to six or seven degrees of hardness, or seven or eight degrees at all events, if the boiling has been continued for half an hour, the length of time during which the tea ought to be brewed to get the most delicate beverage is not more than five minutes, and therefore with a very soft water like that supplied to Manchester it ought not to be more than two minutes. In fact I remember that the best tea was obtained there by pouring the water on to the leaves and almost immediately off again. If you allow a soft water to remain upon the leaves for 10 or 15 or 20 minutes you get a bitter principle out of them, which is unpleasant to me, although I believe it is pleasant to some tea drinkers. Some tea drinkers think that kind of tea the best, and that is more easily got out by soft water than by hard, and therefore from that point of view it might be said that the tea would be more likely to be spoilt by hard water than by soft."

App. D. He further adds that a constant supply of hot water has become almost a necessity in every household, but refers to the difficulties thrown in the way of its attainment by the use of hard water, owing to the formation of thick calcareous crusts in the heating apparatus.

7124. Dr. Miller says:—

"I think that one of the principal objections to hard water is the manner in which deposits take place from it when it is used in boilers. There is always, in our chalk districts, a considerable deposit of hard adherent fur in the inside of boilers, kettles, kitchen ranges, and so on, which in time chokes the range and obstructs the passage of heat, and may occasion accidents. That seems to me to be one of the serious practical inconveniences from hard water which I do not think has been prominently touched upon.

"No inhabitant of London can be unacquainted with that inconvenience?—No doubt they are, and I suppose they feel the inconvenience to some extent."

169. We cannot gather from this evidence any important objection to Thames water, by reason of its hardness, for culinary purposes, except the incrustation in kitchen boilers. With water containing a large proportion of carbonate of lime this would be a serious objection, but practically with the Thames water the inconvenience is not great. A deposit is certainly slowly formed in the boilers or kettles, but it is in most cases of a loose incoherent character, and is removable without difficulty, while in the pipes beyond the reach of the fire very little deposit takes place, and they may remain for years without the necessity for cleaning.

c. For Washing and for Manufacturing Purposes.

170. This is the point on which the greatest stress of the objections to hard water has always been laid; the Board of Health considering that great economy, principally in the saving of soap, would accrue by the substitution of soft water for hard.

171. The Chemical Commission of 1851 say:—

"The injury sustained in washing, from the hardness of the present water supply, is greatly more important; but the estimation of its amount is difficult, and involves the consideration of a variety of circumstances.

"The softer the water the better is it adapted for washing with soap; the earthy salts present causing a definite and calculable loss of soap, which may be taken as amounting, with every gallon of water used in washing, to 10 grains of soap for each degree of hardness of the water. Thus, with one gallon of Thames water, at 14 degrees of hardness before boiling, the loss of soap would be 140 grains and at five degrees of hardness after boiling the loss of soap would be 50 grains; or with 100 gallons of water, the loss in the first case would be 32 ozs., and in the second about 11½ ozs. But such data are not alone sufficient for calculating the saving of soap effected by the use of a soft over a hard water; for soap is used in washing not merely in quantity sufficient to soften the water, but in excess to act as a detergent. The problem is to determine how great the portion of soap lost in softening is, compared with the portion profitably used for washing in the softened water. Such data, however, are not easily obtained. In the bleaching of white goods, as scientifically pursued, soap is not made use of, the process being a series of operations in which the cloth is exposed to lime-water, carbonate of soda, chloride of lime, and acid. The only practice in cotton manu-

factories, where quantities are exactly noted, analogous to common washing, is the soaping of dyed goods; we have found 7 lbs. of curd soap then used with 250 gallons of water, which is nearly 45 ozs. of soap for 100 gallons of water. Now if this water were of 14 degrees of hardness, 32 ozs. more of soap would be required for softening; and of the whole 77 ozs. consumed, 45 ozs. would be available, and 32 lost, which is a sacrifice of nearly 42 per cent. of the soap. With boiled Thames water of five degrees of hardness, 11½ ozs. would be required for softening with the 45 for washing, making 56½ ozs. together, of which 11½ ozs., or about 20 per cent. of the whole soap, is wasted. In the washing of woollens, we find water employed with so much as one-eightieth part of its weight of soap, that is, 200 ozs. of soap with 100 gallons of water. Here the loss of soap by using water of the two different degrees of hardness referred to, being constantly 32 and 11½ ozs., would form a much smaller proportion of the whole soap consumed than before, namely, about 14 per cent. in the one case, and 5 per cent. in the other.

"The maximum loss of soap by the use of Thames water employed cold, would therefore be estimated from such data at 42 per cent. of the soap employed with linens, and 14 per cent. with woollens; or when the same water is softened by boiling, at 20 per cent. with linens, and 5 per cent. with woollens.

"With woollens the loss is too small to entitle it to further consideration, particularly when it is also known that the proportion of woollen articles washed is very small with the poorer classes who frequent the public wash-houses; not more it is believed than two or three per cent. of their whole washing.

"Nor is it to be supposed that in the washing of linen a loss of 42 per cent. of soap is necessarily sustained in all cases. Carbonate of soda is generally employed by laundresses in London to soften water for washing. Indeed, this salt is used in the public wash-houses in a considerably larger proportion than is necessary to precipitate the hardening salts of lime, on its own account, as a powerful detergent, particularly in the first boiling of the linen, and is not omitted although the water is soft, as with the Trafalgar Square water used in the St. Martin's public wash-houses. This use of soda does not appear to be attended by any injury to the linen, with the excellent means of wringing, by which the discoloured water is got rid of, and the abundant supply of cold water for rinsing, which are provided in these establishments.

"The proportion of dyed articles washed by the poor is small, and the colours are generally of a permanent kind which resist soda. In all their washing of woollens and coloured cottons, as well as white cottons, soda is in consequence equally used.

"The following opinion of Mr. W. Hawes is recorded in the evidence upon this subject collected by the General Board of Health, that 'Since the manufacture of crystals of soda at a very low price, and its 'almost universal use in washing, the waste of soap from washing in hard water has been very trifling. 'The quantity of soda used to soften water, as it is called, is a source of expense, but of a trifling amount.' This appears to be strictly true, at least of the washing of the poorer classes as conducted in the public washhouses.

"In regard to the extraordinary injury and wear of linen from London washing often observed, and which has been ascribed to the hardness of the water, it may be remarked, that no such injury to the linen occurs in many private laundries, where handwashing only is practised, and the use of chloride of lime and acids entirely avoided. It is most marked in the larger establishments, where much of the washing of the metropolis is conducted.

"It is in the more careful washing for the middle and upper classes that the advantages of soft water become fully sensible. In the digestion of linen in hot water with soap and carbonate of soda, preliminary to the proper washing, the hardness of the water can only occasion a trifling loss of soda; but afterwards in the wash-tub, where soda is avoided, the earthy salts must occasion a loss of their full equivalent of soap. It is found proper also to avoid boiling any portion of the Thames water that is used in the wash-tub, or even heating the water above a certain point, for the carbonate of lime precipitates on the linen, carrying down the colouring matter of the water with it, and producing stains which there is the greatest difficulty in afterwards removing from the linen. The colour from the water is thus indeed fixed upon the cloth, by the precipitated lime, with the tenacity of a mordant. The evil of the hardness of the water is therefore aggravated by the flood-tinge or clay-colour which the London waters often exhibit for several months in the year.

"The number of gallons of water generally used with a certain weight of soap appears also to be considerably greater in London washing than in the practice of the Lancashire bleachers, so that the waste of soap from hardness cannot fall below, but may exceed, the previous estimate.

"In the washing of the person the saving of soap by the use of soft water is most obvious. For baths soft water is most agreeable and beneficial, and might contribute greatly to their more general use. Its superior efficiency to hard water in washing floors and walls is calculated also to promote a greater cleanliness in the dwellings of all classes, both within doors and externally. While in the occasional domestic washing of linen, the smaller preparation necessary for washing in soft compared with hard water, the saving of soap which would then be sensible to its full extent, and the more easy and agreeable nature of the operation, would make a supply of soft water in a high degree desirable. The use of soda in washing would be gladly avoided by most housekeepers, owing to its injurious action on the colours of certain prints, and the permanent yellow tinge and weakness of fibre which it may occasion even in white linens when exposed to heat before the soda is entirely washed out, as in ironing. A strong desire exists to avoid its use, and where soda is avoided there is no doubt that a saving of about one-third of the soap would be made by washing linen in water entirely soft; supposing the comparison to be made with water of the ordinary hardness of the London supply, but of which one third part was previously softened by boiling. The saving in labour would be even more considerable, if the comparison be still made between washing in soft water, and washing in hard water without the aid of soda."

172. Mr. Bateman thinks there is great advantage and economy in using soft water, because it produces a lather with a less amount of soap; and he refers to the saving effected in Glasgow and Dublin after the introduction of soft water supplies. He estimates the saving in the former of these cities to have amounted to 36,000*l.* per annum. He quotes evidence by Mr. Hawes and by Dr. Clark on the same subject, and also mentions the experience in his own family. 55–63. 66–80.

Mr. Hawksley states that the quality of water most suitable to a large population depends very much on their habits and their necessities with regard to trade and manufacturing purposes. In the north of England, where the great manufactures of the country are concentrated, it is very important the water should be soft, its quality 2504–15.

in other respects being a minor question. He explains the preference for soft water in the manufacturing districts. He points out, however, that the saving of soap is often much exaggerated, the error of calculation in this respect being often enormous. In dyeing, hard water is sometimes advantageous as regards certain colours.

1345–6. Mr. Rawlinson explains that great economy would result in manufactures by the use of soft water, and also refers to its superiority for personal ablutions.

1499, 1520. Mr. Way considers that for most manufacturing purposes soft water has a great advantage. In dyeing they much prefer soft water; the quantity of soap used in this trade is immensely large. For the dyeing proper, however, particularly with bright colours, harder water is considered preferable. At Lyons hard water is preferred. Still the washing process is so much the more important that on the whole soft water is preferable. For brewing soft water is not good, except for the darker kind of beer. It will not brew bitter ale or light coloured beer; all the Burton ales are brewed with hard water. For London porter, however, soft water might be desirable. In washing, the saving of soap and of linen from soft water are undeniable. In scouring cloth this is of much importance. He believes the manufacturers of Yorkshire went to the valleys of the Aire and the Calder more for soft water than for the supply of coal; though now the streams are so foul they cannot use them.

2185–97. Mr. Duncan agrees that soft water is preferable for general manufacturing purposes.

Dr. Letheby gives evidence on this point as follows:—

3938–40. "Are you acquainted with the evidence which was given before the Board of Health, with regard to the economy in the use of soft water, some years ago?—Yes.

"What opinion have you formed with regard to that?—My opinion is, that it is very much exaggerated, and that exactly coincides with the opinion which the chemical commissioners, Messrs. Hofmann, Graham, and Miller, formed of it. I think that those statements which were made by the old Board of Health upon that subject were founded upon wrong premises. They were founded upon the supposition that water was always taken of the degree of hardness that it has in its unboiled condition.

"You would separate the permanent from the temporary degrees of hardness?—Yes, the permanent hardness being that upon which I founded my calculations, while the non-permanent is that upon which the Board of Health founded their calculations; and this makes a good deal of difference in the result."

2646–719. Dr. Playfair states, at considerable length, his opinion that soft water is generally preferable for detergent and manufacturing purposes. He says:—

"Hardness is of the greatest importance as regards the economical use of that water, and its comfortable use for the population. The effect of a hard water upon its ordinary detergent use is seen in the waste of soap and the difficulty of washing which washerwomen experience, and they are far more important members of the industrial community than is generally supposed.

2647. I gather from your statement also that the mass of the population would be likely to be more cleanly, and therefore more healthy, if the water were soft, and less soap were used, than if the water were hard, causing a great difficulty in producing lather?—Yes.

2648. And it is therefore more conducive to health?—Yes, a more thorough cleansing takes place.

2649. So that if it were a question of obtaining either hard or soft water for a population at the same price, you would give the preference largely to soft water, taking all the purposes into consideration?—At a very great difference of price I would give the preference to soft water, because the economy in manufactures is so enormously great with soft water.

2650. Could you give us any illustrations of the economical use of soft water in manufactures?—I could give an instance to show the great difference caused by even a small per-centage of additional impurity in a water. In the River Clyde there is a dam or weir across the river to dam up the fresh water for the supply of the manufactories; below this dam several sewers come in and deteriorate the water very slightly as regards analysis, but very greatly as regards its effect upon manufactures. A piece of calico above this dam, although the difference in value of the water is only about half a grain per gallon of impurities, requires four ounces of madder less to bring it up to the same dye; below the dam of course it requires four ounces more, and the difference of that to an ordinary work where they dye 1,000 pieces a day is 1,562*l.* in the year.

2651. Do you mean that that represents the difference between the use of the water above this dam and below?—Yes, the calico printers dyeing with the water above the dam would save 1,562*l.* a year, supposing they dyed 1,000 pieces a day, which is what good works would do, and they would have to spend that money if they used the water below the dam.

2652. Therefore, that is not a distinction between softness and hardness, but a question of purity or impurity?—In this case the deterioration of the water is owing to its containing iron; the water contains half a grain of oxide of iron below the weir more than it does above.

2705. You have referred to the effect of soft water in the use of dyes; could not that question be looked as in two points of view, one with regard to the economy in the use of the dyes, and the other with regard to the effect of the dyes themselves?—Yes; it has three influences upon dyeing: first, upon the original bleaching of the cotton; secondly, in the waste of the material used in dyeing; and thirdly, in the cleansing or clearing operations after the dyeing is completed; and in all those cases a pure water is preferable to a water containing any hardening matter.

2706. Does not water of a moderate degree of hardness bring out many colours better than soft water?—I have never found it so; I have carefully experimented, and I have found that distilled water brings out the best colours, and in all the experiments that I have made I have found that hard waters do not bring them out so well; but you will get plenty of manufacturers and dyers to tell you differently, and for this reason, that a dyer gets thoroughly accustomed to the water with which he operates, and he uses his materials and his mode of operation to suit that water; and if any other water is brought to him suddenly, seeing he is guided almost entirely by experience, he will get a worse result with a better water, because he is not accustomed to use it; and it requires the experiments of a chemist to elicit those sources of error. Every brewer who has been accustomed to brew with hard water will inform you that hard water is much better and

more suitable for brewing, whereas a brewer who has been accustomed to brew with soft water will tell you that soft water is better than hard; manufacturing use is entirely a matter of experience, in which people suit themselves to the case before them.

2707. Are you acquainted with the experiments of Dupasquier with regard to the effects upon dyes in using distilled water, river water, and spring water?—No, I am not. I may mention that I was once the chemist to large calico printing and dyeworks, and that therefore my attention has been practically directed a good deal to that question. In early life I was chemical manager to Messrs. Thompsons' calico printworks in Lancashire.

Dr. Parkes and Mr. Simon agree with the opinion of Dr. Playfair. Mr. Firth and Mr. Jubb, cloth manufacturers in Yorkshire, state that they find an economy, the one of 25 per cent. and the other of 15 per cent., in soap for scouring by the use of soft water, and they prefer it for dyeing purposes, though for some colours they find hard water do as well; but it appears that their hard water contained iron, in the one case in considerable quantity, and that the total amount of solid residue was 50 grains in the gallon. 3138. 2782. 5212. 5320.

Dr. Frankland considers there is great advantage in the use of soft water in manufactures and for cleansing purposes. He explains the disadvantages of hard water for personal ablutions. As to the saving in soap, he says: 6261. 6277. 6357–8.

"You have, I presume, seen various estimates of what might be the saving if soft water were used instead of hard water?—Yes. 6368–9.

"Do you think that those estimates are generally correct, or do you consider them as rather in excess?—I think that there ought to be considerable latitude allowed in them. I do not think that the estimate would be correct as regards the amount of soap used in personal ablution, for the reason which I have just now mentioned. It is somewhat different in the case of washing linen. Supposing that the water were not softened with soda, then I believe that the estimate would be correct, because you must get the whole of the lime salts precipitated in the water before this washing of the linen can be effectually carried out."

He further expresses his opinion that the advantages of temporary over permanent hardness have been considerably overrated; as water used hot for domestic purposes is either not boiled, or boiled for too short a time to produce the full softening effect. App. D.

Dr. Odling thinks that except for drinking purposes soft water is on the whole preferable to a hard or even to a moderately hard water like the Thames. For manufacturing purposes soft water has great advantages over hard, except in very special cases. 6437–8.

Dr. Miller says there is no doubt that soft water, for all purposes except dietetic, is preferable to hard. There would be a certain saving in soap, but he thinks the amount of saving has been somewhat exaggerated in some estimates which have been made regarding it. As regards personal ablution, undoubtedly soft water is far more agreeable than hard. 7046–53.

Dr. Angus Smith concurs in the advantage of soft water for manufacturing purposes, but he considers the saving in soap has been somewhat exaggerated. 7218–22.

Mr. Heron says that in Manchester the supply of soft water for manufacturing purposes is an enormous benefit. There are many cases where calico printers and others pay a very large sum per annum to the corporation for the water in preference to water which might be obtained at a less cost probably, but which is not of the same quality. The income derived from the water sold for trading purposes is very large, and it is by that income alone that the corporation are enabled to supply the water at the low price they do for domestic purposes within the city. 7343.

173. There is no doubt that this evidence is conclusive and cogent as to the great advantage of soft water over hard for washing and, with some few important exceptions, for general manufacturing purposes; and if we were treating of the supply of a town like those in the manufacturing districts of England, where large quantities of water were required for these purposes, the objection to the present supply would assume a more serious aspect. But the amount of manufacturing industry in the metropolis, of a kind to demand large supplies of soft water, is exceedingly small in proportion to the population, and it must be recollected that the softening influence of boiling largely diminishes the evil. To these exceptional cases, also, the softening process of Dr. Clark would be easily applicable.

There is no doubt also that in personal ablutions and washing generally the use of soft water is more pleasant and economical, but we think the latter advantage has been much over-estimated. The soap is usually applied out of the water, and therefore it is with the small quantity of water adherent to the object washed that we have to deal, and not with the total quantity used for rinsing to remove the soap. It is certain, however, that when a soft water or rain water can be obtained for these purposes it will always be preferred.

All the witnesses have deposed to the general great economy of soft water for most manufacturing purposes, but we find it difficult to reconcile the opinions of some of the witnesses respecting the advantages in dyeing (except on the score of economy) with the fact that the largest and most important manufactories in France for silks, woollens, and

cottons have risen in Lyons, Rheims, Amiens, and Rouen—all using hard waters, and the three latter towns situated in chalk districts. Dupasquier, a well-known chemist, when called upon some years since to report on the waters of Lyons, showed as the result of his researches that waters of a certain degree of hardness were preferable generally for dyeing purposes, so far as regarded brilliancy of colour generally.

On the whole we cannot see that the advantages of soft water in this respect are of sufficient importance to justify going to a great distance to obtain it, in place of the ample supply nearer at hand.

Other Elements of Comparison between Hard and Soft Waters. Action on Lead and Iron, &c.

174. When speaking of the quality of water proposed to be supplied by Mr. Bateman's plan, we have alluded to the danger which may arise in some cases from the action of soft water on lead; and there is, further, the inconvenience of its acting on the iron pipes, leading to the deposition of concretions, interfering with the flow, and eventually destroying the pipes. Several witnesses have deposed to this action, especially Mr. Duncan, who states that at Chorley "they had to take up and relay a number of pipes "in the town, because they had become choked up in consequence of corrosion." In the same way the pipes at Grenoble became so damaged and choked after ten years' use that they had to be removed. A similar thing, but in lesser degree, happened at Cherbourg. Like, however, the action on lead, this action on iron is uncertain and irregular, and may most probably be guarded against by artificially coating the pipes.

From both these evils the water supplied from the present sources is perfectly free. The Chemical Commission of 1851 say: "The water at present supplied may be circulated "through leaden pipes, or preserved in leaden cisterns, with an unusual degree of safety. "The corrosion of water cisterns in London is generally occasioned by the mud which "subsides to the bottom. This corrosion is not attended by any sensible solution of "lead in the water. The London water may indeed be said to exert the least degree "of solvent action upon lead.

"The circulating system of iron pipes appears also to receive a certain amount of "protection from the alkaline character of the present supply. The erosions and bulky "deposits in cast-iron pipes, which have given great trouble in the distribution of certain "waters, are quite unknown in London."

Further, in considering the relative advantages of a water in a dietetic point of view, it must not be overlooked that hard water is less absorbent of gases and of organic impurities, and is therefore less liable to change than soft water. This, it is true, is in most cases a matter of very little importance, but in large towns, and with a poor population, it is to be weighed in the balance.

The Commission of 1851 say: "Putrefactive decomposition appears also to occur less "rapidly in hard than in soft water, and hard water seems to be the more easily preserved "in reservoirs or tanks without deterioration for a short time."

Artificial Softening.

175. It has been frequently suggested that the hardness of the London waters might be removed by the softening process invented by the late Dr. Clark, who has given a full account of it in his letter, Appendix G.

The Chemical Commission of 1851 had so good an opinion of this process, that on the ground of its peculiar applicability to chalk waters, they recommended that these waters, so softened, should be resorted to for the supply of the metropolis. As to its application to Thames water, they, after witnessing certain trials made at the Chelsea Waterworks, came to the conclusion that it was not attended with any peculiar difficulty on the large scale, and that the softening of Thames water in its ordinary condition to a point under four degrees of hardness was perfectly practicable. They estimated that the cost would be about 20*s*. per million gallons. They added, however, the following remarks:—

"The liming process, even when combined with filtration, proved to be unequal to remove the yellow flood tinge of Thames water, nor did it appear to abate an objectionable taste of vegetable matter which the water also then possessed. Had the result been different, the grounds for the adoption of the softening process would have been most cogent. But it seems that it is not to river waters that this elegant and useful purifying process is most advantageously applicable."

4026. Mr. Muir states that the New River Company have been prevented from adopting this process by the difficulty of accomplishing it on a very large scale, and also by the risk of deposit in the pipes. He adds:—

"I think, taking into account the fact that the temporary hardness of the New River water is so much greater than its permanent hardness, that the gain would not be very great; and from the difficulty of applying the

process on a large scale, and the large quantity of water used for sewer flushing and street watering and other purposes (where the softening process is really useless), we have not much encouragement to go into the thing."

Mr. Homersham tells us that he has applied the process with perfect success to chalk waters supplied at various places; the current expenses being about 27*s.* per million gallons. He adds, however, that a river water is not adapted for being softened by it. He says, alluding to the trials at the Chelsea works:— 6762 et seq.

"The effect was this, that if the water operated upon is filtered water, so that it is clear before you apply the lime, the deposit settles quickly and you have no difficulty; but if the water contains any clay or is discoloured by a flood, as river water frequently is, the organic matter in the water, or whatever it may be which discolours the water, mixes with the crystals of the carbonate of lime and alters the specific gravity, and they do not fall down, but keep floating about in the water. The result is, that you must filter that water after it is softened." 6812.

176. Apart from the expense of this process (which would be very large for the whole supply of London), it does not appear to be applicable to the Thames waters on a large scale. It appears more suitable for small districts supplied from chalk wells, or for private use in manufactories where soft water is specially required.

On the Organic Impurities and Contamination of the Thames Water.

177. We now approach the more difficult part of the subject. If the waters of the Thames had no impurities beyond the solid mineral contents, the question as to their wholesomeness and general suitability for the supply of the metropolis would be easily disposed of.

But attention has been called strongly to the *organic impurities* contained in Thames water, which, though more indistinct in their form, and less appreciable in their quantity, are said to be more deleterious in their nature, and to render the water, if not dangerous and unwholesome, at least liable to suspicion.

178. It is easy to understand how streams and rivers may become contaminated with organic matters. The pure rain or spring water, flowing over the surface of the land, will dissolve vegetable matter with which it comes in contact, and if the land be highly cultivated there will also be taken up animal refuse from the manures, or from the droppings of live stock kept upon the farms. But the contamination may go further than this. In spots where the population is collected into villages, the excretions from the inhabitants will often find their way, to a greater or less extent, into the streams forming the natural drains of the land; and in the cases of large towns this effect is artificially aided by the establishment of waterclosets and systematic sewerage.

179. The waters of the Thames are of course liable to organic contamination from all these sources, though perhaps not in so great a degree as is generally supposed. In the first place, as regards the matters, vegetable and animal, washed from the land, it must be remarked that although the greater part of the basin of the Thames is cultivated, and some of it very highly, yet nearly half the area consists of porous permeable strata, such as chalk, oolite, and sand; and that the waters falling on these, except on occasions of large and sudden floods, will be rapidly absorbed, filtering through the earth and going to form the springs. It is from the retentive soils that the washings will be most plentiful and most charged with organic matters.

As regards the excretions from the inhabitants, the basin of the Thames above Hampton is comparatively thinly populated, from the absence of minerals and the non-attraction of any large manufacturing interests. Taking the area of the watershed above the point of intake of the companies, we find by the Report of the Rivers Pollution Commission that the number of inhabitants is about 888,000, and the area is 3,676 square miles, which gives about 230 persons per square mile, or rather less than three to an acre. Then a very large portion of the inhabitants live in villages or small towns dispersed about the agricultural districts, where no regular sewerage is either applied or required, the produce being considered valuable and used for direct application to the land. The population in towns of above 2,000 inhabitants amounts to only about 212,000, and it is only in the larger of these towns, such as Oxford, Reading, Windsor, and probably some few smaller places, that human excrements can be considered as being turned systematically into the stream; and even in some of these cases, from the incompleteness of the drainage arrangements, the effect is at present only partial. Thus it may be shown that only a portion of the inhabitants of the basin can effectively contribute to the sewerage contamination of the river. 2591–5.

180. But though for these reasons we believe that the organic contamination of the Thames is much less than is commonly imagined, still it would be sufficient to do great mischief, were it not for a most beneficial provision of nature for effecting spontaneously the purification of the streams. Some of the noxious matter is removed by fish and other animal life, and a further quantity is absorbed by the growth of aquatic vegetation; but in addition to these abstractions, important changes are effected by chemical action. The organic compounds dissolved in the water appear to be of very instable constitution and to be very easily decomposed, the great agent in this decomposition being oxygen, and the process being considerably hastened by the motion of the water. Now as such waters always contain naturally much air dissolved in them, the decomposing agent is ready at hand to exert its influence the moment the matter is received into the water; in addition to which the motion causes a further action by the exposure to the atmosphere; and when (as in the Thames) the water falls frequently over weirs, passes through locks, &c., causing further agitation and aëration, the process must go on more speedily and more effectually.

The effect of the action of oxygen on these organic matters, when complete, is to break them up, to destroy all their peculiar organic constitution, and to rearrange their elements into permanent inorganic forms, innocuous and free from any deleterious quality. This purifying process is not a mere theoretical speculation; we have abundant practical evidence, which we shall hereafter refer to, of its real action in the Thames and other rivers.

181. The question now naturally arises, can we not, by careful analysis of the Thames water, discover what quantity of organic matters it contains; what is the nature and character of such matters; and how far they are deleterious or otherwise? We have endeavoured to arrive at a solution of this question, but unfortunately without much success. The inquiry seems beset with difficulty. The organic matter is present only in very small quantities, and in shapes and conditions which are very difficult to identify and to reduce to actual measure. The treatment of them is still a problem in chemical science, only now beginning to be effectually studied, and the most eminent chemists are yet by no means agreed either as to the processes most proper to be followed in the analyses, or as to the value and bearing of the results obtained.

It does not follow that all organic matter in water is prejudicial; great mistakes have arisen on this point, as it is often given out that the very suspicion of organic contents of any kind in a drinking water should disqualify it for use. But almost all our drinks other than water owe their distinctive qualities to the varieties of their organic contents, and hence it is clear that the presence of organic matter *per se* is not necessarily prejudicial. It is however necessary, in potable waters which contain organic matter, carefully to distinguish between such combinations as are innocent and such as are noxious; and here lies one of the greatest difficulties.

We now proceed to state the evidence before us on the quality, as regards organic contents, of the water supplied to London.

Earlier Analyses.

182. The Scientific Commission of 1828 called attention to the organic impurities of the Thames water, as taken in the immediate neighbourhood of the metropolis; and added the following general remarks on its salubrity:—

"The statements which have been made respecting the insalubrity of the Thames water as supplied by the companies have also been considered by us, and although, from the few cases which have been brought before us of disorders imputed to this cause, we do not feel ourselves warranted to draw any general conclusions, we think the subject is by no means undeserving of further attention. There must always be considerable difficulty in obtaining decisive evidence of an influence, which although actually operating to a certain extent as a cause of constitutional derangement, may yet not be sufficiently powerful to produce immediate and obvious injury. It cannot be denied that the continued use of a noxious ingredient in diet may create a tendency to disorders which do not actually break out until fostered by the concurrence of other causes, for we unquestionably find an influence of the same kind exerted by other agents which occasion merely a certain predisposition to disease, and of which the immediate operation must therefore be extremely insidious and difficult to trace. It is obvious that water receiving so large a proportion of foreign matters as we know find their way into the Thames, and so far impure as to destroy fish, cannot, even when clarified by filtration, be pronounced entirely free from the suspicion of general insalubrity."

App. A F. The Chemical Commission of 1851, who tested the water with all the chemical skill then attainable, report in the Thames water (then still taken within the tideway) a quantity of organic matter varying from 1½ to 3 grains per gallon, on which they remark as follows:—

"The soluble organic matter from two of the Thames waters was submitted to ultimate analysis, and found to give 0·105 grain of nitrogen in the Grand Junction water, and 0·031 grain of nitrogen in the Southwark

and Vauxhall water. The existence of nitrogen is generally supposed to imply the animal origin of organic matter, and on such evidence a minute and probably unimportant portion of animal organic matter would be admitted to be present.

"None of the waters had any marked taste or odour, nor betrayed any indication of putrescence, either when first taken up or after being kept in bottles for several weeks at a temperature between 50° and 60°; nor even after remaining in close vessels for two weeks at 80°.

"In these waters when submitted to microscopic examination no animalcules were observed in any case. But the period of the year was not that at which any considerable development of animal life is to be looked for."

They allude to the colour and contamination to which the river is liable in the late autumn and early winter, from the extensive decomposition of vegetable matter, which they state to be a serious evil; but they appear to draw, in a sanitary point of view, a broad distinction between this and organic matters of animal origin, on which they remark as follows:—

"As the main drain of a large and populous district, the Thames becomes at all seasons polluted by the sewerage of several considerable towns, and by the surface drainage of manured and ploughed land. At the same time, we doubt whether the existence of organic contamination from town drainage is at present perceptible in the Thames above the reach of the tidal flow, or amounts there to a sensible evil. The indefinite dilution of such matters in the vast volume of the well aërated stream is likely to lead to their destruction by oxidation, and to cause their disappearance. The river may reasonably be supposed to possess, in its self-purifying power, the means of recovery from an amount of contaminating injury equal to what it is at present exposed to in its higher section."

They add further observations tending to justify a recommendation that the supply should be drawn from a point above the tideway.

Messrs. Hofmann and Blyth's analysis in 1856, made after this recommendation had been carried out, in pursuance of the Act of 1852, showed in a striking manner the advantage of the change. The chemists found that the hardness and mineral contents had undergone little variation; but in regard to the organic matter they reported as follows:— App. B G.

"*A very considerable diminution, however, is observed in the amount of organic matter.*

"In fact, in 1856 the water supplied to the metropolis contained not more than one-half of the organic matter which was present in the year 1851.

"This result is certainly not accidental. The diminution is not merely an average result, but uniformly observed throughout. The waters examined in 1851 were taken in January; those investigated in 1856, partly in January and partly in April. The diminution of the organic matter cannot therefore be due to the influence of the season. Nor can it be due to any difference in the mode of determining the organic matter in 1851 and 1856. These determinations were made by exactly the same method; for it so happens that the analytical part of the inquiry in 1851 which refers to the organic matter was likewise made in the laboratory of the Royal College of Chemistry. The diminution is obviously partly due to the alteration of the localities from which many of the companies derive their supply. The Grand Junction, the West Middlesex, the Southwark and Vauxhall companies, formerly supplied respectively at Kew, Barnes, and Battersea, derive their present water from Hampton; the Lambeth Water Company used to take their water at Lambeth, but have now erected extensive works at Thames Ditton. The diminution of the organic matter in the London water supply is, however, by no means confined to the companies that have changed the locality of their source, and it must therefore be attributed in a great degree to the considerable improvement which has taken place in the collection, filtration, and general management of the supply of water to the metropolis."

The analyses of Letheby, Odling, and Abel, in 1867, state that the quantity of organic matter in the filtered water could not have exceeded one grain per gallon, and shew the ammonia to be almost infinitesimally small. The average total quantity of organic matter in the water supplied in 1867 appears only about two-thirds of that in 1856, and only about one-fourth of that in 1851, showing the beneficial change effected from further improvements in the supply. App. A H.

In the Returns of the Registrar General, there are now given monthly reports by Dr. Frankland on the condition of the waters supplied by the different London companies. The analyses which accompany these reports show a general agreement with those just referred to. As, however, they are elaborated on a principle not ordinarily employed, it is not easy to compare them with those of other chemists. They give very careful and definite determinations of organic matter, but on the value of the mode employed, and on some of the inferences, there is a difference of opinion amongst men of science; and we shall presently have to make some remarks on this subject.

183. We have had before us many witnesses conversant with the subject, including some of our ablest chemists, and have endeavoured to ascertain fully their opinions on this question, which we will now give, as far as practicable, in their own words.

Evidence on the Organic Impurities of Thames Water.

Chemists and Medical Men.

184. Dr. Lyon Playfair, Professor of Chemistry in the University of Edinburgh:—

2681. Will you allow me to ask you whether in soft water the same proportion of organic matter would not be more injurious than in water of an ordinary degree of hardness, and what would be the effect of the presence

of organic matter in such water?—The effect of organic matter in the water depends very much upon the character of that organic matter. If it be a mere vegetable matter, such as comes from a peaty district, even if the water originally is of a pale sherry colour, on being exposed to the air in reservoirs or in canals leading from one reservoir to another, the vegetable matter gets acted upon by the air and becomes insoluble, and is chiefly deposited, and what remains has no influence on health. But where the organic matter comes from drainage it is a most formidable ingredient in water, and is the one of all others that ought to be looked upon with apprehension when it is from the refuse of animal matter, the drainage of large towns, the drainage of any animals, and especially of human beings.

2682. No doubt a large proportion of organic matter of such a nature would be injurious, but in ordinary cases of a river, such as the Thames above London, the action of the aëration of the water would be in that case to destroy any moderate amount of organic matter, would it not?—It would gradually, but such matter becomes insoluble more slowly than the matter of which I have been speaking; and in any case the presence of it is dangerous, and as one does not know the stage to which the oxidation has gone, the presence of any such animal matter in water is always most objectionable. It is impossible to tell at what stage it is by a mere general examination; by a chemical examination you can do so, but the presence of the most highly oxydised form of organic matter when it passes into the stage of nitrate is, I think, quite sufficient to condemn the water, because you are never sure whether it has fully passed into that stage.

2683. Is it not considered that by the time the Thames water, with which London is now supplied, reaches the delivery pipes all organic matter is converted into the state of nitrates and nitrites?—I think that the evidence from the cholera of last summer was quite conclusive on that point, that it was not.

2684. That was confined to one particular district, was it not?—Yes.

Mr. Simon, Medical Officer to the Privy Council:—

2751. You of course have analysed, and you are well acquainted with the quality of the London water?—Yes.

2752. What is your opinion as to its character?—Judging by chemical analyses, performed on it in what I may call its normal state, I am not aware that there is much fault to be found with it.

2753. You are speaking now of all the water supplied by the various companies?—Yes, speaking quite generally. Speaking of it in its broad ordinary chemical characters, as it would be reported on from a chemical laboratory, I should say it is a fair water supply.

2754. Are you now speaking of the whole supply of the metropolis?—Yes, speaking generally of it. But what I thus say of its average chemical constitution in its normal state does not touch the question of the water's liability to accidental very dangerous pollutions. There are dangerous qualities of water supply, with regard to which, so far as I know (but I do not speak as a skilled chemist), chemists are totally unable to measure, even to demonstrate, the fatal influence that a water may have. A water may be, for instance, capable of spreading cholera, but chemists be unable to identify the particular contamination which produces that effect.

2812. My practical point is, that what one has to do is not to take water out of a reservoir or out of a tap and give it to a chemist and say, "Tell me, is this wholesome water"? What one has to do is to guard the supply with the utmost strictness against every foul admixture. It ought to be made an absolute condition for a public water supply, that it should be incontaminable by drainage.

2837. Have you, apart from the question of sewage, considered the condition of the Thames basin as a gathering area, having regard to the high state of cultivation of the land and the use of manures, artificial and other, and the washing of water into the Thames, what the effect upon the water would be for domestic purposes?—The earth is a most powerful absorbent and disinfectant of the materials used as manure, and I do not think that practically any important danger would attach to the outflow from cultivated lands.

7135. I think when you were examined before you were asked your opinion as to the effect of sewage contamination in rivers, and after how long a period, and at what distance of flow, the river would get rid, if at all, of that sewage contamination; have you formed any opinion upon that point?—I cannot venture to answer that question with any confidence; it is a very difficult question to answer.

7136. But are you of opinion that the water of a river which had been under the influence of such contamination would ever after be a safe water for domestic purposes?—The answer to the question, if it is to be absolutely correct, must vary with the quantity of sewage, the volume of water, and the distance between the point of contamination and the point to which the question applies.

7137. Supposing that sewage is discharged from one of the sewers, say, at Windsor, would it be possible to detect the presence of that sewage seven miles lower down the river, having regard to the volume of water in the river?—I believe it would be absolutely impossible for chemists to discover it, but the practical sanitary question is different. Supposing tape worm eggs to be sent into the river with that sewage, would those tape worm eggs be alive seven miles down? Or, supposing cholera discharges to be sent into the river, or the discharges of typhoid fever, and assuming (which is a frequent pathological opinion) that the respective contagia of typhoid fever and cholera are living germs, would those germs be alive seven miles down? It is not a question whether a chemist would find out the organic matter so much as it is a question whether those particular molecules would still have their property seven miles down. I cannot say that they would not.

7138. Could you detect them at that distance?—Only by their effects.

7139. Might not the same disease be produced from any other cause?—The particular parasite will only come from its particular egg. You would not get hydatids except from eggs any more than you would get chickens without eggs.

7140. Are the Commission to understand you to state that it is impossible for a chemist to discover the existence of sewage at the distance named?—The possibility varies with the conditions I have stated.

7141. If it is not possible for a chemist to discover it, is it not presumptive evidence either that it does not exist, or that if it does exist it is in such minute quantities that it is in no way deleterious to human health?—I am very decidedly of opinion that that principle is not a safe one to adopt as a basis for sanitary regulations in the matter. I think the rule ought to be that no sewage should go into any water that can be used for drinking purposes. I think, even, that allowance should be made for the proper decent taste of people. Water into which sewage has been discharged is, in relation to the matter now under consideration, an experiment on the health of the population, and I do not think that that experiment ought to be tried. Moreover, as a mere matter of taste, people would rather not drink water into which sewage has been discharged, and I think that that in itself deserves consideration.

Dr. Farr, Superintendent of the Statistical Department of the General Register Office, has given us lengthy information as to the outbreak of cholera in 1866 in the East of London, and has put in valuable statistics, &c., thereon. The following extracts will illustrate his general views :— 2845 et seq.

2876. Am I to understand you to say that in those districts where the cholera prevailed very largely the principal cause was the impure water?—I conceive that the cause of cholera existed here, and that the elements of disease from cholera patients were distributed all round London. Cases occurred in every part of London, but in the other districts the mortality was inconsiderable. For instance, in all the districts supplied by the Grand Junction, the West Middlesex, and the Chelsea Water Companies, the mortality was about 3 in 10,000, in those supplied by the Southwark and Lambeth Companies, which were formerly so heavily visited, it was about 6 in 10,000, and in those supplied by the New River Company about 8 in 10,000, but in those supplied by the East London Company from the Old Ford reservoirs it was 79 in 10,000. I do not ascribe the whole of that mortality to the water, but I ascribe a large portion of it to the circumstance that the impurity causing cholera was distributed through the water of that company.

2877. Will you be good enough to tell us what you consider those other circumstances to be?—The density of the population also had an influence. We found that where people were packed very closely together they suffered more than where they were distributed more widely over the ground. We have found also that the condition as determined by the annual value of the houses that the people lived in, their poverty had a considerable influence, but not so striking as I should have imagined it would have had. We found also that the elevation of the ground in which the people were living had a very marked influence. In the first report I showed that the mortality on the low banks of the Thames both on the south and on the north side, was from 100 to 150 per 10,000, but as you ascended on successive terraces the mortality was reduced, and at the higher points it came down to 8, so that the elevation of the soil had a considerable influence. That I have been led to suppose since had a good deal of influence upon the purity of the water also.

2890. Do you think that if this London water could be free from all its impurities it is a good quality water for consumption?—I confess that when I see that this Loch Katrine only contains in 100,000 grains three grains of impurities of any kind, and that it contains no trace whatever of sewage or anything like sewage, I should have greater confidence in water brought in that way from the hills than I should in water taken from the river; at the same time I am not prepared to say that the water from the river, with great precautions as to letting sewage into it, might not be made a very decent sort of water.

2929. As far as your experience goes, are we to take it that this view which is conveyed in the report of Dr. Frankland is one that you concur in, namely, that at the present moment taking his analysis there is nothing that is really bad in the water supplied to London?—Not on that particular day. I should qualify it myself always in that way. I can conceive that the character of the water varies from day to day; it varies with the temperature and with the rainfall, and with a variety of circumstances. All we know is that from the analyses which Dr. Frankland has hitherto made he has come to the conclusion that the water supplied to London has contained something very noxious, but that it did not contain anything noxious at the time that he took it at the mains.

Dr. Parkes, Professor of Military Hygiène in the Army Medical School at Netley :—

I have made a list of diseases all of which are occasionally communicated by means of water, not solely communicated by water, but occasionally. For example, typhoid fevers; of which I have collected about 23 instances of local outbreaks of severe typhoid fever, and some six or eight more, the particulars of which I have not got, are known to me, arising from water impregnated with typhoid sewage, or possibly with simple sewage.

3123. As far as your special observation has gone, in all cases where there has been a discharge of human excreta into water where the parties have been suffering from typhoid fever, that has generated disease in every district where the water has been taken for domestic purposes?—It has not generated typhoid fever in all cases, because in some cases it has generated diarrhœa and dysentery; typhoid fever has prevailed in some cases and not in others, and therefore that is an argument in favour of the view that it requires the typhoid sewage especially to pass into the water for the development of that particular fever, and that simple sewage will not cause it. But the question is surrounded with difficulties; it is so difficult to get reliable scientific evidence that it is still *sub judice*.

Dr. Parkes proposes to divide potable waters into several standard classes. He says :—

I would propose to form a class of "wholesome waters," under which two sub-classes of waters may be included, first, the purest and most wholesome water, which is free from suspended matters and contains very little dissolved organic matters, say under one grain per gallon, and that probably vegetable, and of dissolved mineral matters under seven grains per gallon. That will include all the best waters supplied from the primitive rocks, and from some of the sands which contain under that quantity of mineral matter, and is probably the purest water on the whole which can be obtained in that way.

Then the second sub-class in the first order would be what I would call pure and wholesome water, to which no objection can be taken, I believe, in a sanitary point of view, but which is not so pure as the former. This water is also free from suspended matters, having dissolved organic matter under two grains per gallon, the greater part of that being vegetable. Of dissolved mineral matters it would contain under 12 grains per gallon, consisting principally of carbonate of lime and alkaline carbonates and chlorides. That second sub-class would include the best chalk waters, which are often very free indeed from organic matter. Then the second grand class I would make I would propose to call "useable waters;" waters which cannot, perhaps, be very much objected to, not so good as the former class, but yet which in many cases might be used, and which would not produce, perhaps, any bad effects. Those are all waters with no suspended matters or suspended matters easily separated by the coarse filtration usually resorted to by the water companies. The organic matter would be chiefly vegetable, but it should not exceed three grains per gallon, owing to the diseases which would probably arise if it exceeded that quantity, and if the organic matter is apparently of a mineral origin it ought not to exceed two grains per gallon. Then it should contain mineral salts not exceeding 20 to 30 grains per gallon, and consisting of a class of salts which do no injury to the system, such as alkaline carbonates, alkaline chlorides, chloride of sodium, and chloride of potassium, in less quantity, and possibly a little carbonate of lime also.

3149. The third class would be what I would call "suspicious water," which would be any water with much matter suspended, which would be separated readily by coarse filtration. Such a water as that would in all probability contain either fine particles of mineral matters, which are hurtful, such as clay, or possibly it might contain suspended organic matters very finely divided, and not very readily separable by filtration. It might contain dissolved organic matters vegetable and animal, amounting to about three or four grains per gallon, and mineral matters of large amount, such as alkaline and chlorides, carbonates, and carbonate of lime in large amount, that is to say, perhaps over 9 or 10 grains per gallon, or sulphate of lime or magnesia, and chloride of calcium or magnesium in certain quantities; all those I should consider make a water suspicious; or if it contains any indication of nitrites, nitrates, ammonia, &c., showing that organic matters had passed into the water and had there been oxidized; any indications of that kind I should consider would bring the class under the head of suspicious water. Then the fourth class would be "impure water," which would include any turbid and bad smelling water with suspended matters not easily separated by coarse filtration; also dissolved organic matters above four grains per gallon, especially if of animal origin, large quantities of mineral substances, especially of sulphate of lime and sulphate and chloride of calcium and magnesium, which all give permanent hardness to the water, or large indications of nitrites, nitrates, fatty acids, ammonia, &c., all of which indicate the passage of organic matters, animal in all probability, into the water.

3150. Under which of those heads would you put the London water?—I should put the London water under head No. 3, suspicious.

3151. Would you do that because there are indications of nitrates?—Yes; I should call any water containing large indications of nitrates and nitrites suspicious water. Such indications may, however, come from water not impregnated with sewage, as some soils give off nitrates and nitrites. . . . . I think that the mere presence of nitrates and nitrites in water in small quantities would not be hurtful at all; their importance is as indicating their source, and showing that there must have been contamination, probably by animal inorganic matter, in most cases sewage, and of course rendering the chances of such organic matter passing in in sufficient quantities to affect the health very probable, but when such organic matter has been oxydized, then no doubt it becomes, at any rate in most cases, harmless.

3160. Sewage is the most dangerous parent of those things, is it not?—Yes. But any indication of them should lead at once to an examination, so as to trace the origin of nitrates and nitrites, and the water would be suspicious in the proportion that it contained any large quantity.

3161. It would not be a certain inference that it was from sewage?—Certainly not.

3177. Is there in your judgment an objection to the Thames basin as a gathering area for water by reason of the high state of cultivation in some parts, and from the manuring that it undergoes?—Yes, I think there is a very great objection. No doubt the effect of water passing through a soil with manure is to cause a very rapid oxydation of the organic matter, and a very large quantity is converted into nitrates and nitrites and ammonia, but there is a limit to that, and it is impossible to ensure the safety of water where there is the possibility of contamination on a large scale with organic matters derived from sewage.

3178. If it passed through a sufficient depth of earth it would be deprived, would it not, of this matter?—The earth would be a great purifier, no doubt.

3181. Have you observed in a case where sewage has been discharged into a river that after running for three or four miles the effect of that sewage has been destroyed?—Yes, we have that in the case of the Southampton water supply; some sewage passes into the Itchen river, but it is quite destroyed by the time the water is distributed in Southampton, at least there is no detectable quantity.

3182. What is the distance?—The distance is six or eight miles. I could not undertake to say the distance in which water would purify itself in that way, but there is no doubt that it does purify itself, although in what distance, or what time, or under what precise circumstances I could not say.

3183. I presume that the sewage, probably by the action of the water and the atmosphere, would really be broken up into other elements of a less injurious character?—Yes, broken up into compounds of nitrogen and ammonia, nitrates and nitrites.

3184. You do not get rid of it, you have it in a different form?—Yes.

3185. And in a less objectionable form?—Yes, in a form I presume quite unobjectionable in a small quantity. A very large quantity might be irritant, but in a case in which they would be in water not very largely impregnated with sewage, I should think that they would not be hurtful.

3186. Do you think, taking the upper part of the Thames as a gathering area, that any injurious result from manuring or other washings into the river would by the course of such water down the Thames be somewhat neutralized?—I think that very likely it would be neutralized to a very considerable extent. That would rather depend upon the amount passing in; if any experiments could be made as to the amount of manuring and the number of acres that would furnish sewage matter, and the amount of sewage matter which would pass in, and the rapidity of the flow of the Thames at different parts of the year, and the volume at different times in the year, we should be able to form a better idea. It would be modified by a great many circumstances.

3187. But there would in your judgment be a process of purification going on?—Yes, it would be simply a question of degree.

3237. Do you think that in point of health the population of London generally suffer from any impurity in the existing water apart from any special case of cholera in the east of London?—I think that where the population of every town shows a considerable amount of diarrhœa, and also of typhoid fever, it makes one believe that there must be some impurity in the water at times, and the health of the population as regards those diseases of the intestines seems to be very much influenced by the purity or impurity of its water supply.

3245. If the subject had been considered one of vital importance by the medical profession generally, do not you think it would have been proposed that it should be scientifically investigated by some specially appointed body either of medical men or chemists?—We must remember with regard to the effect of different things upon the health of the community in this country that it has only been the subject of investigation for the last 30 years. Till we began to have statistics of deaths we had not learnt to know the relative prevalence of the several forms of disease, and it was impossible to form any opinion as to the condition under which the people were living. We may say that these questions are almost in their infancy.

Dr. Letheby, Medical Officer of Health to the Corporation of London:—

3879. Having regard to those waters, and the several tests which you have yourself made, what is your opinion generally of the water supplied to this metropolis?—My opinion is founded in the first place upon the actual analyses of the waters over a long period of time, monthly analyses; it is founded in the next place upon

an observation of the use of those waters very extensively, and I am bound to admit that there is no evidence whatsoever that those waters are in any way objectionable as a public supply. I am now speaking of the whole of the metropolitan waters.

3880. Notwithstanding the amount of organic impurity, that is your opinion?—The organic impurities are not large in the London waters. The loss by incineration, although a grain, is not regarded as a serious quantity, because the loss by incineration represents a great deal more than the organic impurities.

3891. When that interception takes place, will the water of the Thames in your judgment be greatly improved?—I do not think that it will be much improved. Not but that I am quite ready to admit that the discharge of sewage into such a river is a most improper thing, but considering the powerfully oxydizing influence of water upon sewage, the many agencies which are at work destroying it, the power of precipitation, the using of it up by vegetables and aquatic plants and by fish, and above all by the power of oxydization, I think that none of the sewage discharged into the Thames can at the present moment be discovered at Hampton, but nevertheless it is very possible that there may be a still further improvement of the Thames water by the adoption of these measures. Certainly there will be an improvement in this manner, that if the discharge of the sewage into the Thames were to go on increasing during the next 20 or 30 years, as it has been during the last 20 or 30, we should then probably have such an excess of sewage in the water of the Thames as would render it very unwholesome. But at the present moment I cannot perceive through the most refined chemical processes the existence of a particle of sewage in the water at Hampton where the Thames Companies take their supply.

3894. Have you at all ascertained in what length of time or distance polluted matter will be decomposed and transformed in its chemical qualities; for example, supposing we had the sewage from Richmond poured into the Thames, how far down the river would it be lost as sewage and broken up into other chemical elements?—I have made a very great number of chemical experiments to determine that. I have examined most of the rivers in England, and this is the conclusion that has been come to, not only in my mind but in the minds of all the engineers who have devoted their attention to this subject, that if ordinary sewage, containing we will say nearly 100 grains of solid matter per gallon, such as our London sewage, out of which probably something like 14 or 15 grains are organic, be mixed with twenty times its bulk of the ordinary river water and flows a dozen miles or so, there is not a particle of that sewage to be discovered by any chemical processes.

3898. Taking the case of the cholera disease and the discharges from the human body being mixed up with the sewage, do you consider that any germs of that disease would be carried down in water?—At the present moment we do not know what the germs of the disease are. If the germs of the disease be decomposing matter, then I do not think that they would exist in the water; but if the germs of the disease be living matter, then it is possible that they may exist in the water, but as nobody as far as I am informed can tell us what the germs of cholera are, it would be premature for me or anybody to theorize as to the probability or the possibility of their existing in the water.

3901. You are aware that it has been alleged that the main cause of the cholera in the east end of London was due to the water supply, do you entertain that opinion?—No, I entertain the opposite opinion. It was a matter of duty with me to investigate the whole of the circumstances connected with the East London supply. In the first place it was supplied to the hospital to which I am attached, in the next place it was supplied to the eastern division of the city, where, as officer of health, it was my duty to look well into the matter, and in the third place I had a general interest in it scientifically, apart from any official connexion with the subject, and I was very desirous to ascertain whether or not the water had been in any way concerned in the propagation of the disease. I therefore investigated it very fully.

3902. Are there two distinct waters supplied to that district?—Yes, but I will tell you this with regard to it, there is hardly anybody who can say, except in certain parts of the East London Company's district, whether the water had come from the reservoir at Old Ford or whether it had been received from the filter beds at the Lee, which is considered to be a good water, for the water was oscillating backwards and forwards in the mains in such a manner that the engineer himself had no knowledge what water was in any main at any particular time. But on the other hand there are places at which Old Ford water, and that water alone, is supplied, namely, Stamford Hill, Upper Clapton, Walthamstow, Woodford, Wanstead, Leytonstone, North Woolwich, and Silvertown, and excepting the two last-named places there was no cholera in any of them; there was a little in Silvertown towards the end of the epidemic, but the other places were free from it, and those were the only places where we actually knew that that water did go.

3904. Do you think the present supply of water to the London people is wholesome water?—I do, a thoroughly wholesome water.

Mr. Wanklyn, Professor of Chemistry at the London Institution, Finsbury, informs us that his attention has recently been directed to a new method of analyzing water for organic matters, and which he now considers sufficiently perfect to be worked. The preliminary experiments he has made show a larger quantity of free organic matter in the Thames water than Dr. Frankland's method, which he considers cannot detect all the nitrogenous matter. He says:—

. . I have to remark that the method of determining the organic matters which I use is a very simple one, and can be carried out in about three hours, and the determination is a perfectly direct one. I do not determine the total nitrogen in a water and then determine the nitrogen present as ammonia and nitric acid and give you the difference, but I determine directly the nitrogen present as organic matter, and that you will see is an important thing. The project of 10 years ago, (and it has been tried to be carried out, and it is admitted that it will be very difficult to carry it out,) was to give you the organic matter by a double process, giving you a difference; but my method is a direct one. I give you directly the nitrogen which is present in the organic matter.

5482. It has been stated in evidence before us that if you pour into water a volume of sewage equal to five per cent. of the volume of water into which it is cast, the water will so operate upon it in deodorizing and destroying and breaking up its elements into its primitive elements in fact, that it would no longer be sewage or possess any of its noxious qualities You apparently hold a contrary opinion?—This I am sure of; the urea in the sewage in such a water would be very readily broken up into ammonia and carbonic acid, and a little exposure would dispose of the urea, but the albumenoid matter in sewage is extremely persistent, and one of the results of the

whole investigation is this, that albumenoid matter is very persistent indeed, and you could not depend upon any treatment such as you have mentioned getting rid of the albumenoid matter.

5485. But will not certain changes take place, even in the albumenoid matters?—Yes, certainly; but the change is very slow, and it is very irregular. The change in urea is very rapid, so that you have to operate upon water recently taken in order to get your full quantity of urea.

Mr. Wanklyn subsequently sent us further testimony in a letter (Appendix A K), which is to the following effect:—

The result of a prolonged examination carried out by myself, Mr. Chapman, and Mr. Smith on the water supply of London, Manchester, Glasgow, and Edinburgh, last summer is the following:—

The water of the Thames at Hampton Court, where the companies draw their supply of water, is not very good, as it exists in the river; but after the filtration effected by *some* (but not all) of the companies, it becomes excellent, and in point of purity from organic nitrogenous matter is then fully equal to the water supplied to Manchester, Edinburgh, or Glasgow.

The water supplied by the New River Company is also very good.

Dr. Frankland, Professor of Chemistry in the Royal Institution and the Royal School of Mines:—

6222. What does your experience tell you is the effect of the quality of the present supply in London upon the health of the population generally?—I cannot of course trace any direct connexion between the present supply and the health of the metropolis; but I consider that water contaminated with sewage contains that which is noxious to human health. There is no process practicable upon a large scale by which that noxious material can be removed from water once so contaminated, and therefore I am of opinion that water which has once been contaminated by sewage or manure matter is thenceforth unsuitable for domestic use.

6224. Are we to understand that you are of opinion that this noxious matter exists in the water from analysis, or from knowing that sewage runs into the river from whence the companies draw their supply?—From both circumstances.

6225. Take the analysis first. What leads you to believe that there is that amount of sewage matter in the water which would be detrimental to health?—I find on analysis, as is shown in the table at page 17 of our report, that there is present in the waters delivered into London the following quantities of material, which may be regarded as the skeleton of the sewage which has been previously poured into the water; namely, of nitrogen, in the form of nitrates and nitrites, a mean quantity of ·192 part in 100,000 parts of water, that is, in the Thames water; in the river Lee water, as delivered by the New River Company, ·221 part in 100,000 parts; in the water delivered by the East London Company, which is also river Lee water, ·132 part; and in the chalk water delivered by the Kent Company, ·365 part in 100,000 parts. This skeleton, as I have called it, of previous sewage corresponds to the following quantities of average filtered London sewage, namely, in the Thames water to 1,751 parts of sewage in 100,000 parts of water; in the river Lee water, delivered by the New River Company, to 2,013 parts of such sewage; in the river Lee water, delivered by the East London Company, to 1,077 parts of such sewage; and in the chalk water delivered by the Kent Company, to 3,393 parts of such sewage. I must mention, however, that this chemical record is defective, especially in the summer months. It is defective in one direction, namely, that it gives the minimum amount of sewage only, with which the water has been contaminated; because in rivers we have vegetation in a state of activity during the spring and summer months, and also to some extent in autumn, and those aquatic vegetables remove this skeleton of the sewage to a greater or less extent from the water.

6226. You state that you have come to the conclusion that sewage has been the cause of the contamination of this water because you find a skeleton there in the form of nitrates and nitrites?—Yes, and also of ammonia, which I think I omitted to mention, but that is a very insignificant part of the skeleton.

6227. Is it possible that those nitrates and nitrites could be present in the water without its having been contaminated by sewage?—Could they be produced by some other cause than that of sewage?—They could be caused by manure thrown into the water, and by manure applied to the land.

6228. But are they attributable to nothing else?—To nothing else, I believe.

6233. With regard to the Kent water, we had some evidence yesterday to the effect that you must have been mistaken in finding traces of sewage in those chalk wells, the water being taken at a depth of 250 feet in the chalk, and the upper part of the wells themselves being lined; therefore the water must have filtered through the chalk, and there could be no trace of the skeleton of sewage. Is it your opinion that the skeleton of sewage as you describe it will find its way down to a depth of 250 feet, and that after filtration through gravel, and ultimately through the chalk, its presence will still be detected?—There cannot be a doubt about it, that this skeleton of which I speak, but which is a very different thing from the sewage itself, is present. I have never stated that the water which has filtered through the chalk in this way contains unaltered sewage; it is this inorganic skeleton of sewage that I find in water so filtered.

6234. Is it prejudicial to health?—It is not in a moderate quantity, such a quantity, for instance, as is contained in this chalk water of the Kent Company.

6235. With regard to the Kent water, the mean of the nitrates and nitrites according to the figures which you have just given us is ·365, and that amount in water in your opinion would not render it injurious to health?—That amount of nitrates I should say would have no deleterious effect upon health.

6236. It is scarcely necessary to say that in the case of the water delivered by the East London Company, which has ·132, the water of the New River Company, which has ·221, and the Thames water delivered by the Chelsea and Grand Junction and other companies, which has ·192, none of those four waters as at present supplied to London could have an injurious effect upon the health of the metropolis, in consequence of the presence of those nitrates which you say are the skeletons of previous sewage contamination?—Certainly not. Those nitrates would not in any case, I believe, be in the least prejudicial to health; but they reveal the fact that those waters have been previously contaminated with sewage, and, as I have already stated, there is no method which, with certainty, can be applied to water by which the noxious qualities of sewage can be effectually removed from it.

6237. But in all those four waters, as I understand you to say, after having had them analysed, you find the presence of those nitrates and nitrites, which shows that the waters had been in previous contamination with sewage?—Yes.

6238. But although they are in that state, you state, do you not, that there is nothing in them that could be injurious to health, and therefore the water is a wholesome water to drink?—I did not intend my statement to go so far as that. I meant only with reference to those nitrates in themselves, that the skeleton of the former sewage which is represented by nitrates and nitrites is not injurious to health; but we have no guarantee that other portions of that sewage may not have escaped the process of filtration through the chalk, and filtration through the land or over the land, and may be present in that water. Those substances are in too minute a quantity to be capable of detection by chemical analysis.

6239. Then your answer would apply as far as the nitrates would enable you to judge?—As far as the nitrates themselves are concerned that quantity of sewage matter which they represent is an innocuous form in the water.

6240. The presence of what other elements would lead you to a conclusion upon the quality of water as regards health?—In the first place when water is once contaminated with sewage, there is no process to which it is afterwards subjected which will effectually remove all that sewage contamination from the water. Filtration will not do it in certain cases, at all events. I have proved that the excrements of cholera patients cannot be filtered out of water; that after a degree of filtration which I believe is never attained by the water companies, and rarely attained perhaps by the passage over soils in irrigation, this water still remains opalescent, from the rice-water evacuations with which it has been mixed. The degree of danger which still remains in waters from different sources varies obviously according to the amount of filtration that the water undergoes. I would much rather drink the chalk water of the Kent Company, even if it had been contaminated to four times the extent of the Thames water, than I would drink the Thames water, because if I could have the assurance that none of that sewage or manure water had found its way into the wells through fissures in the chalk, the chalk water having passed through say 100 feet of chalk, would be very much better filtered than any water which finds its way to the Thames.

6241. When you speak of the difficulty of removing the effects of sewage contamination, does that difficulty apply to that which is held in mechanical suspension, or to that which is held in solution?—To that which is held in mechanical suspension. I believe that the noxious part in sewage is that which is held in mechanical suspension, not that held in solution.

6402. Still you are able to detect those globules?—No, they are beyond the reach of the chemist, and so far of the microscopist, I believe.

6242. Will no system of filtration remove it?—I would not say that it is impossible to remove it, but no system of filtration will secure its removal. There are only two processes by which it can be effectually removed; the one is by boiling for a long time, and the other is by distillation; and therefore it is that I say that, inasmuch as those two processes are impracticable on a large scale, in my opinion water that has once been contaminated by sewage ought not afterwards to be used for domestic purposes.

6244. Then are we to understand you to say that no amount of filtration would render those waters fitted for the supply of the metropolis?—As I have stated, no process of filtration that has hitherto been devised will remove choleraic dejections from water; and inasmuch as it is generally believed that the noxious matter of sewage exists there in the form of minute germs which are probably smaller than blood globules, I do not believe that even filtration through a considerable stratum of chalk could be relied upon to free the water perfectly from such germs.

6246. Do I correctly gather from your evidence that you think that no water that had passed over or through any cultivated district would be proper for the supply of the metropolis or other large towns?—I do think that that water is not safe for human consumption afterwards.

6247. That being your idea, would not it follow that no water could be supplied to the metropolis in a wholesome state from the Thames basin, because the whole of the Thames basin is as we all know very considerably cultivated?—Yes, I think it is very likely that that would be so; and inasmuch as the chalk water from shallow chalk wells exhibits this previous sewage contamination, I should infer that the springs feeding the Thames would also exhibit that contamination; but that does not necessarily follow, because it is stated that the deep chalk wells furnish a water free from nitrates and ammonia, or very nearly so, and consequently they are not so contaminated.

6248. Do you think then that there is a point below which the sewage matter would not get down?—At all events there is a point apparently below which the skeleton of the sewage no longer finds its way, it is either consumed by some living organisms and converted into other forms of matter, or it is absorbed by the strata themselves through which it passes. I have not myself analysed the waters of the deep chalk wells, but Mr. Dugald Campbell has done so, and he states that they are free from nitrates.

6278. Apart from the degree of hardness, in searching for water for the supply of a town, what should you be most careful in avoiding, having reference to the health of the population?—In avoiding a water which had ever been contaminated with sewage or manure matter.

6279. You stated, did you not, just now that the previous contamination, so far as it had ended in the formation of nitrates and nitrites, was of no importance?—That portion of the sewage which has been converted into nitrates and nitrites is of no importance.

6280. Therefore generally that might be left out of the question also?—Yes, so far as that itself is concerned.

6281. Apart from those two elements of consideration, what should you consider the substance to avoid?—In any water nitrogenous organic matter would be a substance to avoid.

6292. You conclude that it is very difficult to get rid of sewage matter by running water?—I do. That portion of it which remains undecomposed after its passage through the sewers oxydizes with extreme slowness. About four-fifths of the nitrogenous matter contained in fresh sewage, which has just been produced, as it enters the sewer is decomposed before the sewage, after a run of two or three miles, emerges into the river, and the remainder, I believe, as far as my experiments teach me, is decomposed with extreme slowness afterwards.

6296. Reverting to this particular question of the presence of organic nitrogen in those waters, what do you consider to be the effect upon water of the presence of organic nitrogen, whether derived from an animal or vegetable source?—As far as we know, the presence of organic nitrogen in the form of vegetable organic matter, such as peaty matter, is innocuous, unless contained in a considerable quantity in the water; but when contained in the water in the form of sewage matter it is believed to be noxious.

6297. Did I rightly understand you to say that you cannot distinguish in those cases whether it be derived from vegetable matter or from animal matter?—I have said that until recently it had been impossible to distinguish between the two, but that now I considered that the proportion between the carbon and the nitrogen in the two cases afforded a basis from which we could in many instances, decide.

6298. That is only an indirect method?—Yes, because the analysis itself gives no difference between the nitrogen from the two sources.

6328. It would seem that you could not very well refer the presence of nitrates and nitrites in all waters exclusively to previous sewage contamination. Without contesting that that may in many cases be so, are there other causes in operation which may have produced the same result?—There are, undoubtedly, causes which will produce a result of that kind to a certain extent. We have the presence of those materials, as I have already mentioned, in rain water, and it is conceivable that rain water falling upon a very dry sandy district, and evaporating there mostly from the surface, might leave those nitrates behind, and they might accumulate there to some extent from that source, and they may also be produced by the decay of purely vegetable matter. This strict analysis of water for nitrates is comparatively a new thing, and it is possible that we may find sources of those nitrates which we are at the present moment not aware of. But it is a remarkable circumstance that waters which it is well known cannot be contaminated by manure or by sewage never do contain those nitrates in a proportion bringing them near to the point of contamination.

6372. Then you do not accept the theory that sewage discharged at point A, and travelling down the river, is so oxydized as it passes a distance of six or seven miles, and is so entirely destroyed that its original elements are not to be found, but it is converted into some other substance or substances which are not detrimental to human health?—I believe that that is by no means a generally true proposition. I believe that under favourable circumstances, that is, when the water is warm, and there is a large volume of water, and the water is a good deal agitated in its course, that effect may be produced so far as regards the dead organic matter in the sewage, but not at all as regards the living germs that may be present in that sewage.

6382. And with regard to that which you do say is injurious [the unoxydized portion of sewage], you are hardly able to detect it?—Only rarely. Those waters are examined only on 12 days out of the 365, that is one point that must be taken into consideration. And I have only, in the case of the entire water supply, been able to get evidence which I consider anything like conclusive on this one occasion to which I have already alluded, namely, last month, on the 21st of January, when those waters contained this large proportion of organic nitrogen as compared with the organic carbon which they contained.

6383. That case to which you refer in January was quite exceptional, as I gather from your report of the 31st of January?—Yes; during the whole of the three years that I have examined these waters I have never found them in so bad a condition as upon that occasion, or in a condition approaching to that, but I may say that this condition of things having once set in lasted the greater part of a month.

6384. In this report of the 31st January you again repeat the words which I have just quoted; after giving the amount of sewage contamination in the water of the Chelsea Water Company, you say: "By gradual "oxydation, partly in the pores of the soil, partly in the Thames and its tributaries, and partly in the reser- "voirs, filters, and conduits of the company, this sewage contamination had been converted into comparatively "innocuous organic compounds before its delivery to consumers," and I think I find that almost word for word in all your weekly reports?—It is copied, in fact, from one to the other; it goes through the whole of them.

6385. Would that not rather lead the public to take it that your view was that this water was perfectly wholesome, or as nearly as possible perfectly wholesome?—I think it would, and that was the impression which I intended to convey, so long as I had not actually detected the presence of sewage matter unoxydized in the water; at all events I was very anxious not to convey the impression that analysis had discovered anything actually injurious in the water.

6386. Do you agree with those remarks of your friend Dr. Odling, which are separate from your report, "Although London is at present provided with an agreeable and in my opinion perfectly wholesome water," &c.?—No, I do not consider it a perfectly wholesome water, I did not at the time this was written, and that, I believe, caused my colleague to give a separate postscript to this report.

6389. In the month of January this year in your report you say: "The waters delivered in London during "the latter part of January by the Chelsea and especially by the Southwark and Lambeth companies, were "in such a muddy condition as to render them totally unfit for domestic use." On that point, filtration properly carried out would have met, would it not, that part of your objection as to the water being muddy?—Yes, certainly.

6390. From that we may gather, may we not, that your view would be that the question of the proper filtration of the waters is one of vital importance?—I think it is a very important point.

6391. You also state in your annual report: "The New River Company stands alone in the perfection of "its filtering apparatus. On no occasion during the past year has this company's water exhibited the slightest "turbidity, thus proving that perfect filtration is compatible with the largest daily supply furnished by any "one company in London." Do you see any reason why every company should not give out their water in the same perfect state that you here describe the New River Company does?—I see no reason whatever why the other companies should not.

6392. And do you consider that it would be a desirable thing in case of necessity that such a delivery of water in a pure state should be enforced by legislative enactment?—I do; in fact, it is so enforced at the present moment.

6426. What should you consider the essential conditions of a good drinking water?—The essential conditions of a good drinking water I should take to be, first, coolness and aëration; secondly, freedom from animal organic matter of all kinds; thirdly, that it should never have been contaminated by sewage or manure in any form; and, fourthly, that it should be soft water, not over five degrees in hardness.

Dr. Odling, Professor of Chemistry at the Royal Institution and at St. Bartholomew's Hospital:—

6447. You have examined the Thames water from time to time, have you not?—I have examined it fully.

6448. Have you found in those examinations of the Thames water the presence of sewage not decomposed?—I have not.

6451. Has your attention been directed to the important principle of the self-purifying process which is going on in rivers running at a given velocity?—Yes, it has. There may be great differences of opinion as to the degree to which that self-purification takes place, but that it does take place to a very considerable extent I think is undeniable.

6452. You will understand my question as not referring to sluggish waters, but to rivers where the body of water would become exposed to the action of the atmosphere as it passes along?—You may see in many rivers, even sluggish rivers, having sewage discharged into them, that for a mile or two the appearance of the river is affected by the sewage, but beyond a certain distance there is no recognizable effect at all, the weeds are perfectly clean and perfectly healthy.

6453. Do you know Leicester at all?—Yes.

6454. Do you know the condition of the river there?—Yes, I do.

6455. Near to the town it was in a very bad condition, and the water quite black, was it not, when you saw it, from the refuse of manufactories and the discharge of sewage?—Yes.

6456. Did you observe the condition of that river three miles from the town?—Yes, and from its appearance you could not tell that it had been contaminated, it was running clear, with fish swimming in it, and the weeds were clean.

6457. And that simply from the process of self-purification?—Quite so.

6459. You have not detected any of the skeleton forms which Dr. Frankland has given utterance to?—That is a point on which I am a little at issue with Dr. Frankland with regard to the interpretation to be put upon the presence of nitrates in water. It is admitted that the presence of nitrates says nothing for the present condition of water at all, and I rather dispute that it says anything very important for its history. There is no doubt that a very large quantity of sewage, or the equivalent of sewage, is discharged into the river Thames above the source of the present water supply, and I do not mean to say that Dr. Frankland exaggerates that proportion at all—I do not know whether he does or does not—but I contend that the estimation of the nitrates in a water does not give any ground on which to estimate its proportion of sewage.

6460. But when found are they in your judgment injurious to the water?—In such quantities as are found in the river supply of London they are, in my opinion, perfectly innocuous.

6461. Still less, I suppose, if found in chalk?—Yes, quite innocuous if found in chalk.

6462. Is it your opinion that those which have been found in chalk are due to sewage?—It is a point upon which there is no positive evidence, but I am inclined to think that it is not so, for we find them distributed so irregularly. For instance, the deep well water at Trafalgar Square, and the deep well water from the greensand, and lower chalk all over London, is nearly free from nitrates and nitrites; whereas the water of equally deep wells elsewhere in the chalk is found to contain very considerable quantities of nitrates. The deep well water from nearly all formations has been found to contain nitrates. Then, moreover, a proportion of the nitrates which the sewage itself undoubtedly does furnish, in one case is destroyed and in another case is not; and so far as the history of the water is concerned, in the one case where the nitrates are destroyed, that water may show but a very small amount of previous sewage contamination, whereas it might have had a much larger amount than the other.

6463. Apart from the question of sewage, is it your opinion that the condition of the Thames basin is such as to render it an unfit gathering ground of water for domestic purposes?—I do not think it at all unfit.

6467. Do you agree with Dr. Frankland, that supposing a system of perfect filtration were adopted (and he appears to consider that the New River Company has a perfect system of filtration), and if all the companies were to use the same process, we should have a water perfectly wholesome for domestic purposes?—Certainly I do.

6472. The presence of nitrates, if not in excess, is a comparatively unimportant element?—It is an unimportant element as to its state, and I believe it to be in many cases an unimportant element as to its history.

6473. You have heard the questions that were put to Dr. Frankland with regard to the probable origin of nitrates. Are you of opinion that their origin may be traced to several sources?—I am quite of that opinion.

6474. With regard to the presence of nitrates in the deep chalk wells of the Kent Company that have been referred to, they show a quantity of nitrates present as large or larger as in the Thames water; but it does not follow, does it, that they are necessarily derived from the same source?—Certainly not.

6477. What do you consider to be an essential quality of good water for drinking purposes?—It should be bright, colourless, and brisk, and it should not contain any considerable amount of nitrogenous matter.

6479. Do you think that there is no risk in using for drinking purposes waters which are derived from rivers the population on the banks of which is constantly increasing?—Of course it is conceivable that the amount of impurity discharged into the river may exceed the power of the river to purify itself, or approximate so nearly to that power as to leave a balance that it would not be safe to rely upon.

This gentleman also makes the following remarks in his report (Appendix D.) on the analysis on the Welsh and Cumberland waters:—

Although London is at present provided with an agreeable, and in my opinion perfectly wholesome water, still it is evident that for general town supply a soft water such as that of Wales or Cumberland is upon the whole more suitable than a somewhat hard water such as that of the Thames and Lee; and, further, that a water which neither contains nor has received sewage impurity is at any rate preferable to a water which certainly has received, even though it does not actually contain any such impurity.

Sir Benjamin Brodie, Professor of Chemistry in the University of Oxford:—

6986. It has been stated in evidence before this Commission that in the case of sewage discharged at Windsor into the river, and flowing down the stream six or seven miles, or rather more, at that point they have failed to detect the presence of the sewage, that from oxydization or the breaking up of the elements it is in such a condition that they have found nothing which in the judgment of the witness would be prejudicial to human health. Have you made any observation bearing upon that point?—I have not myself made any observations on that point, and indeed I do not know how such an examination could be satisfactorily conducted.

6988. Have you formed any opinion as to the probable effect of the flow of seven miles upon water contaminated with sewage, whether at the end of that distance or any other distance it would be fit for human use, or could be considered to be a safe water?—The sewage would be during its course to a certain extent oxydized and destroyed, and resolved into other compounds, but how shall we say that all the sewage is resolved and destroyed so that the water should be safe. To do that we must be able to apply some extremely sensitive test to the water which would enable us to ascertain the presence or the absence of sewage in it, and I want to know what the test is which we are so to apply. There are causes operating, as we all know, to destroy the sewage which, to a certain extent, will effect that end, but the question, as I understand it, is whether those causes are really adequate to destroy the sewage not partially, but absolutely and entirely, during a given course of the river.

6991. You have been supplied with a copy of the medical evidence which has been laid before the Commission, and no doubt you have observed that we have evidence on both sides, one party alleging that water impregnated with sewage will be purified by the action of the air and oxydization in its course a few miles down the river, but, on the contrary, Dr. Frankland states very distinctly, that water once contaminated with sewage is unfit for human use, and that you will still find what he calls the skeleton of sewage present,

although it may have travelled 100 miles and been exposed to filtration?—I think what is asserted by Dr. Frankland is true, that there are no known causes in operation on which we can adequately rely to remove the sewage from the water. That causes are in operation which partially remove that sewage and diminish its injurious effects is true, but the question is whether those causes, as I said before, are adequate to produce a complete result; that is to say, whether they will take out of the water all the injurious matter which is contained in it, so as to render it fit for drinking. I do not think it possible, in the present state of our knowledge, to pronounce an absolute opinion upon that point. But if you ask whether it is wise to drink water into which you have put sewage, knowing that you have no positive means of getting that sewage out of it, that is a question which anyone can answer for himself, assuming always the injurious character of sewage. I am not now pronouncing any opinion upon that point, or saying in what degree sewage is injurious; that does not appear to me to be a chemical question. I think that is a question of very great importance, but which is much more likely to be solved by other agencies than by chemical experiments. Medical statistics will tell you more about the injurious or non-injurious character of sewage water than any analysis would do. It does not seem to me that we have, as I before said, any accurate chemical measure of the sewage in the water, at all events I do not know what that measure is. I have read the evidence which has been given by Dr. Frankland and one or two other witnesses also before this Commission, but I still hold to my opinion that we have no accurate measure of the sewage matter in the water, or even of the previous sewage in the water.

7004. In all those analyses a certain value is ascribed to previous contamination, as determined by the presence of nitrates and nitrites in the water; will you give your opinion whether the presence of nitrates and nitrites is to be ascribed to that one source alone, or may it be ascribed to several sources?—I think the probability would be that the presence of a large quantity of nitrates and nitrites would indicate the previous presence of organic matter in the water; but I do not know that you could take that nitrogen, in the shape of nitrates, as an absolute measure of that organic matter, which is a different thing.

7006. But is it not possible that in many cases such salts may be derived from other sources than that of previous sewage contamination, using that term in its common acceptation; may they not arise from other matters in the soil, and therefore is their presence a fair indication of previons sewage contamination?—I believe that nitrates may occur from other causes, but I cannot speak from positive experience.

7009. Dr. Franklin considers that this organic nitrogen in the London water is of a different value from that in the lake waters, because the proportion of organic carbon to the nitrogen in the waters is different?—Yes. This appears to me a very important fact, and may really indicate that the organic matter in the water had, in two cases, a different origin.

7011. You think that the tests of the greatest delicacy are yet insufficient to determine the point at which sewage ceases to be present?—I may take a case which really is an absolutely analogous case to the case of water, namely, the case of the atmosphere. You may look at the atmosphere as really a great ocean. Gases from drains are being discharged into this gaseous ocean just as the water from the drains is going into the river. Those gases are so diluted when they get into the atmosphere that chemical analysis is absolutely mpotent to reveal their presence in any given portion of the atmosphere. But nobody can doubt the njurious effect, under certain conditions, of the gases and other organic matters present in the atmosphere. Take the case of the Westminster drain, the opening of which is known to have occasioned a great outbreak of fever here. You say that you would not live in a house next it, nor at the end of the street, nor at the end of the next street; but where should you begin to live so as to be safe from the effluvia of that drain? We cannot answer that question. I suppose if I get to Oxford I am safe from that drain, but we have no chemical tests,—because that really is the only point at issue,—to apply to the air to say whether or not it contains injurious or poisonous organic matter from the drain. In the atmosphere just as in the water there are constant processes going on with great efficiency to destroy those noxious gases; and a person would argue, just as is done in the case of water, that you have sulphurous acid from the chimneys of London, you have the oxygen of the atmosphere, you have nitric acid, you have ozone in the atmosphere. All these agents, happily for us, are at work destroying those noxious gases from the drains and sewers and other places. But when is their work completely done? That is what we do not know. Another most important thing is this, that really there is no reason whatever to believe that the injurious character, either of sewage or of the gases from a drain, depends, fundamentally, upon the quantity of that sewage or of that gas; in all probability it far more depends upon the quality of the sewage, namely, what it consists of. Now what is the nature of the poisonous matter in the atmosphere or in the sewage? We do not know that at all. Therefore how can you possibly say when that poisonous matter is got rid of from the water or from the air. It is a question that with the means at our disposal it is absolutely impossible to answer; and I say as I said before, that I think you have a much better chance of getting at these relations through accurate statistics properly applied, than you have through chemical analysis, because chemical analysis is one of the poorest things possible to reach those delicate quantities. You cannot get at those small quantities at all. Chemical analysis must be limited by our power of weighing and measuring; we can only do those two things. We can weigh and we can measure, and we can do that with a certain accuracy, and there we stop; but that accuracy is not capable of being multiplied *ad infinitum*. It may go on to a certain point, but we cannot go beyond that point. I think that it is impossible absolutely to answer those questions, for we have not the data; but the question arises, as I said before, whether a prudent person likes to drink water which contains a certain quantity of nitrates and nitrites, or that when analysed is found to contain a certain quantity of organic carbon and nitrogen, water into which you have deliberately put cartloads of sewage at some time or other in its course.

7014. Oxydization is constantly going on in the soil and in the river, and therefore there must be some point at whichcthe perfect destruction or oxydization of this animal matter must take place?—What I think is muh more important still is another point, namely, the great dilution of the material, and I should rely upon the dilution quite as much and more than upon the destruction of the injurious matter. Supposing the sewage of a large town such as Oxford pouring into the river, there are numerous feeders and tributary streams to the river which effectually dilute the sewage. The sewage is gradually getting proportionately less and less, and therefore its noxious character diminishes and ultimately disappears.

7028. It is a perfectly possible and conceivable thing that a very minute proportion indeed of sewage in the water might be most extremely injurious to health. I say that partly from general experience, and partly because I have had occasion myself very frequently to observe the vast importance in chemical changes of what people so frequently pass by as inappreciable quantities of matter. Indeed, I have occasion to see more and more every day that minute portions of matter, which previously were not suspected at all to exist, exercise important influences on chemical transformations.

7041. If water is supplied to a town from a river which in a part of its course has received previous sewage contamination, and if that water is used on a large scale by that town and produces no ill results,

and chemical analysis fails to detect anything unusual in its character, is it not a fair presumption that such water is wholesome and good water for the use of a town supply?—If it be used without injury to the inhabitants, really chemical analysis is altogether superfluous. But the question is whether it can be always and permanently so used. That seems to me to be the real point at issue. We should have found out long ago the injurious effects even of small quantities of sewage if the sewage were always injurious; but that is not asserted. It is only supposed that, under certain exceptional conditions, even sewage may become very injurious. The injurious character of a water impregnated with sewage matter might not be discovered for years. You might long go on using it, for years, and it might not be discovered, and yet you might have some outbreak of disease in the place which, nevertheless, might be connected with the use of that sewage water.

7043. You consider then that with regard to the effect of water upon the health of the inhabitants, it is rather a question for the medical observer than for chemical analysis?—I really think so. I think that chemical analysis is not yet sufficiently advanced (whether it ever will be I do not know) to pronounce a decision upon the matter, and that you have a better chance of getting at the real connexion between the injurious matters in the water and diseases generated by those matters through statistical observations carried on upon a large scale than through chemical analysis. Statistics elicit relations of cause and effect on which you cannot deliberately experiment.

Dr. Miller, Professor of Chemistry in King's College, London:—

7066. What was [in 1859] the state of the water at that part of the river above Teddington lock where the water companies are now taking their supply?—Above Teddington lock the water was very good, even at that time when there was but a scanty supply of water in the river.

7068. Did you detect in the water taken from above Teddington lock the presence of sewage?—There was organic matter, but I should not have called it sewage.

7069. Did you then form an opinion that it was traceable to sewage or partially traceable to sewage or to some other cause?—I did not specially determine whether it was sewage matter or what the origin of the organic matter was.

7070. Would there be a difficulty in determining whether the nitrates were due to one source or partly to one source and partly to another; for instance, the drainage of land, the manuring of farms upon the watershed, and the washing of the remains of the sewage into the river?—I do not think there is any means of determining what proportion of the nitrates is due to the natural supply from the chalk springs, and what is due to the oxydized sewage. In fact there is no means of determining that. They exist exactly in the same condition in the water, and therefore a proportion of the nitrates may be due partially to the one cause and partially to the other, the proportions varying with accidental circumstances.

7072. You have seen the evidence of Dr. Frankland in which he refers to the presence of sewage in the form of skeleton; if the view which he takes is a correct one would the presence of that skeleton be injurious to health do you think?—I understand that merely as a figurative expression showing the existence of nitrates and ammonia in the water. Neither of those things in themselves in small quantities is in the least degree injurious. I am speaking now simply of them after they have been completely converted into that condition of nitrates or of ammonia.

7074. You are aware Dr. Frankland takes a very strong view of the presence of that skeleton of sewage, because, in referring to certain wells used by the Kent Waterworks Company, where the water is pumped from a depth of 250 feet through the chalk, notwithstanding the filtration at that depth he still detects the presence of those skeletons of sewage?—That is to say, he finds nitric acid or nitrates, and he assumes what I think he is not justified in assuming, namely, that those nitrates are the result of the putrefaction, or rather of the decomposition of sewage matter. No doubt they are formed by that operation in a great number of cases, but to say that they are always formed so would be, I think, far beyond what the facts warrant.

7077. I do not deny or doubt that in a great number of cases the presence of nitrates does indicate the previous existence of some organic contamination. The only difference between Dr. Frankland's view and mine is this, that he assumes, apparently in all cases, at least if I read his evidence aright, that nitrates invariably point to previous sewage contamination. I think that that is not justified by other observations. The experiments of M. Boussingault and others show distinctly that the formation of nitrates does occur where there can be no suspicion of previous sewage contamination.

7082. Are you of opinion that water once contaminated with sewage can never be considered a safe water afterwards?—I think experience is quite against that. I think it is safe; evidence shows that it is safe in the majority of instances. There may be cases in which danger is produced.

7088. Have you made any experiments upon the power of water, in a given course, to oxydize organic matter?—I ascertained a remarkable result in the course of the summer of 1859 upon the river. I took specimens of the water at Kingston, at Hammersmith, at Somerset House, at Greenwich, at Woolwich, and at Erith on the same day, and I examined the quantity of oxygen which the water contained at all those different points. I found that the quantity of oxygen at Kingston was the ordinary or normal proportion; at Somerset House it was much diminished; at Greenwich the whole of the oxygen had disappeared; at Woolwich it was much in the same condition, and at Erith the water was very much improved, showing that this diminution of oxygen had been produced by its action upon the water contaminated with the sewage of the London district, and that as it passed lower down the oxygen was again absorbed from the air, and again it became diluted with a large volume of water from below, from other sources, the Lee, the Ravensbourne, and other tributaries, and in this manner the water had again become oxydized. I look upon this as a direct proof of the effect of oxygen in destroying those organic contaminations which are thrown into the river.

7099. You consider, do you not, that in small quantities the presence of such nitrates would be innocuous?—Yes; the presence of large proportions of nitrates would no doubt indicate communication with some source of animal refuse. Well waters in towns very commonly contain large quantities of nitrates, especially in the neighbourhood of graveyards.

7100. But they contain very unusual quantities?—Yes, quite large quantities; sometimes I have seen as much as 20 grains in a gallon.

7101. Have you had occasion to analyse any waters which you have reason to believe are removed from the possibility of previous sewage contamination, and yet found nitrates present in them?—Yes, the waters from Watford, which come from chalk wells, where there can be no suspicion of previous sewage contamination, always contain nitrates.

7104. Organic nitrogen, I presume, is the substance the presence of which in any excessive quantity is to be avoided?—The presence of organic nitrogen may be derived from substances which are quite harmless,

or it may be derived from substances which are very injurious, and we have no means of distinguishing between the two. Nitrogen is always present in such combination, not as nitrates, and not as ammonia; but the presence of nitrates is always a suspicious circumstance in water, and the greater the quantity of nitrates the more suspicious is the nature of the water and the more reluctant one would be to use such a water as a source of supply.

Dr. Robert Angus Smith, Government Inspector of Alkali Works :—

7184. Have you directed your attention to the quality of waters supplied for domestic purposes?—Yes, I have.

7185. Have you made any analyses which you can refer to as giving information on that point?—I have made a great many analyses, but I have not brought any with me. I only intended to speak here on general principles, and especially about the organic matter which seems to have raised a discussion of more importance than, I think, any other subject in connexion with water.

7186. Will you be good enough to state your views upon the subject?—Some time ago, in studying the organic matter of water, I divided it into many parts. It had been common in analyses of water to write down the organic matter as if it had some special quality. Afterwards, however, I found it necessary to consider organic matter as a very complex substance, and instead of putting it down under one head I have put it down under at least eight heads, and some of those heads have subdivisions. The first head which I think it would be worth attending to is organic matter, which is putrefied. This would include the gases and vapours arising from putrefaction, and this is the thing which strikes one more especially on coming in contact with water which is impure; for example, in drinking it would be offensive to the smell, and generally it will give those characteristics that were found in the Thames some two or three years ago. I examine this part by means of permanganate of potash. It is very readily done.

7187. As I understand it, although you break up that which is usually designated organic matter into eight parts, still those eight parts form but one matter that is called organic?—It is so; it is one of the great divisions.

7188. None of those eight parts would have reference to anything except the original matter which is called usually by chemists organic matter?—No; but they will be as different in their properties as, I may say, organic or inorganic matter are—so widely apart are they in quality. It is difficult for one to give exactly all the particulars, but I will first say how I examine the gases of putrefaction. I use generally permanganate of potash for that purpose; that was the plan adopted by Professor Vorckhammer, of Copenhagen, some years ago, for organic matter generally, and it has been adopted by several chemists since, and rejected by several others as of no value. I find that it is of value. . . . . I may say what I found in the Thames. Above Reading very little impurity was found in the Thames, but below Reading it was very marked indeed, and it never disappeared in any part below Reading.

7198. For what distance down?—Any part. I went down to London Bridge, and it was visible in any part below Reading.

7199. Did you detect the presence of sewage from every sample that you took below Reading to London Bridge?—Yes, what I believe to be caused by sewage; it was organic matter, which in its decomposition showed a great deal of animalcular life, and which I believe to indicate so much organic matter of a very active kind, probably dangerous.

7200. Supposing there had been no source of contamination below Reading, would you then have been able to detect the presence of sewage in the river, because, as you are aware, down the river there are fresh sources of contamination going on?—Yes, I think there would have been a little. I may say that above Oxford I considered the water extremely pure, but below Oxford and I might say down to Pangbourne, it was, perhaps, a little less pure, but very little. I considered at that time that it was not proper to take water from any source below Pangbourne at any rate. Perhaps I might be inclined to go higher now, but that was my view at the time when I examined the water for the Metropolitan Sanitary Commission, which is now 20 years ago nearly.

7201. Are you of opinion that a water once affected with sewage contamination is never after a safe water for domestic purposes?—I think it may be quite safe. It is so in some cases, in others not.

7202. Under what condition?—Supposing it were very impure indeed, the first thing that would occur would be putrefaction; that gives out a number of nauseous gases, and the most prominent to the senses is, perhaps, sulphuretted hydrogen. After the putrefaction had finished a great deal of the organic matter would be removed. If any remained, and it were exposed to oxydation nitrates would be formed. Those nitrates are, I consider, so far offensive as they indicate very bad company, but in small quantities I am not aware that they can be considered hurtful. On the contrary, to some extent they are a very valuable accompaniment of organic matter. They themselves are disinfectant and prevent processes going forward which would be unpleasant. . . . . If the germs pass into rivers we do not know how far they may be carried; on the other hand, we do not know that they ever can be carried in pure water; the dissolved oxygen may destroy them, as it unquestionably does putrescent matters. A positive proof of their transmission in otherwise pure water is wanting. We might ask if a cholera germ in the water at Oxford would produce disease in London; and we might answer by asking if one cholera germ passing into the air at Woolwich would produce disease in Pimlico. This we do not know; but it seems probable that disease cannot be carried far by pure air or by water with much oxygen in it, which is equal to pure air. We are informed that the atmosphere is full of germs; but the evidence seems to be that it requires an unusual excess to attack us successfully. It seems to be a question of quantity. Still there is the sentiment remaining; we do not like that any sewage should enter the water that we drink. I am disposed to think it well to listen to this sentiment, so far as large towns are concerned, although even then we must remember distance and quantity; but so far as villages and ordinary agricultural drainage is concerned, I am not aware of any experiments showing sufficient room for fear.

7242. Are we to understand you that you would be guided as to the objectionable quantity of organic matter in water rather by the results showing the development of animalculæ than by the results of chemical analysis?—I think that one of the most important experiments that can be made, although I would not neglect the others. I have seen some very striking instances indeed, in which an enormous number of animalcules have been found in water which at first appeared perfectly pure, and quite a contrary result has taken place in water which I thought to be inferior.

7244. I understand you also to say that if you give the water a sufficient length of flow this organic matter will be oxydized more or less completely?—Yes, that is always the case. It is a question of length of flow, or length of storage, or depth of drainage; those are the three most important points.

7247. The nitrates are what I have called old organic matter. There is no doubt that by the oxydation of nitrogen compounds nitric acid is formed. I imitated this process long ago, using chiefly yeast, and so produced nitrates from yeast or vegetable matter. The nitrate comes from animal and vegetable albumenoids indifferently. When estimating the London sewage we may readily refer most, if not all of it, to animal matter or sewage. In the river above London some of the nitrates come I do not doubt from vegetable matter. I have not estimated how much comes from one and how much from the others. I am inclined to think that nitrates coming down may be divided into the animal and vegetable nitrates, and measured. Albumen, &c., would produce nitrates without being used by animals. When nitrates are caused by matter from animals there is always a corresponding amount of common salt. Men take from 200 to 300 grains at least of common salt every day, and it is given out every day. This is the most unchangeable accompaniment of sewage.

7253. In most cases where there is danger to be apprehended from the presence of nitrates have you not been able to detect the presence of chlorides?—Always. Whenever chlorine is high in the water it is necessary to look for nitrates derived from sewage, and, as a rule, it is so constant that there is scarcely any exception. When we find much more than the average quantity of chlorine in a well water, nitrates are found also, and if the water in a district is pretty well known, that is to say, if the amount of chlorine in water from any district is pretty well known, and a specimen of that water should indicate rather more chlorides than usual, you may conclude with almost certainty that it is from sewage.

Messrs. Letheby, Odling, and Abel, in the analyses for the metropolitan water companies, given in Appendix AH, add the following remarks:—

With reference to the second part of your letter, in which you request us to report on the system pursued by Dr. Frankland in obtaining and recording his analytical results, we have to offer the following few remarks.

Without discussing the question of the general applicability of Dr. Frankland's method of water analysis, which are at present we believe almost exclusively employed by him, we must express our dissent from one of the inferences which he founds upon his analytical results. In particular, we contend that the proportion of nitrogen discovered in water, in the forms of nitric acid, ammonia, &c., is not a trustworthy measure of the extent to which that water has, at some time or other, been contaminated by sewage, inasmuch as the nitrogen compounds existing in a water may, on the one hand, greatly exceed, and, on the other, equally fall short of those which would be furnished by the addition to the water of a given proportion of sewage (using the latter term in the broad sense in which it has been applied by Dr. Frankland), thus, for example, we cannot accept as a correct representation of the relative condition of the East London water (from the river Lee), and that supplied by the Kent Company from deep wells in the chalk, the statement of Dr. Frankland in the Registrar General's Weekly Return for May last (No. 22, page 179) that the former contains 0 parts of previous sewage contamination (estimated) in 100,000 parts of water, while the latter exhibits 3,540 parts of previous sewage contamination in the same amount of water.

It scarcely need be pointed out by us, that the apparently higher results which Dr. Frankland's published analyses record, as to the solid constituents generally existing in water, when compared with those given in the reports of other analyses, are simply ascribable to the circumstance that they are calculated on 100,000 parts of water instead of on the imperial gallon of 70,000 parts, as is the general custom.

In conclusion, we have to express our opinion that no useful results, but the reverse, can be attained by expressing in large multiples, as in tons (see Registrar General's weekly returns), the small proportions of mineral or other constituents, which analysis discovers in potable waters, and by designating as *impurities* perfectly harmless substances which exist, in varying proportions, as normal constituents of nearly all natural waters.

Engineers and others.

185. The Rev. J. C. Clutterbuck:—

1805. You are well acquainted, are you not, with the surface condition of the watershed of the Thames for some hundred miles up?—Yes, all the way.

1806. Is it highly cultivated?—It is highly cultivated, decidedly.

1807. And what, in your judgment, would be the effect upon the water in the rainfall passing through a soil so cultivated?—With reference to the chalk surface, I do not conceive that there would be any great amount of effect produced by cultivation on the water percolating that part of the country, because it would sink through so very much soil.

1810. Looking at that general condition of the surface and at its geological formation, is there in your judgment any objection to that gathering area for water for the purposes of domestic use?—No, I think not, I cannot say that I see any.

Mr. Hawksley:—

2553. The great complaint of London water at present is not the quality of the water itself so much as the polluted district through which it passes?—That, I think, there is the greatest possible amount of misconception upon; there is a great deal of prejudice, not unnatural at all, but still amounting to prejudice, upon that question. I believe, in fact I know, that the water of the Thames at Hampton is very excellent water, very pure, very free from organic matter, and that what little organic matter it does contain is of a very innoxious character.

5076. What quantity of water, as compared with the volume of sewage, is necessary for the purpose of breaking up into its original elements the sewage which has been discharged into it?—Generally about 20 to 1. If the water flows rapidly and is very much disturbed, so as to be continually receiving fresh oxygen, a smaller quantity, even 12 to 1, will effect the process; if it proceeds very tardily it may take a little more; but usually 20 to 1 is perfectly abundant. I could give you very remarkable instances. Take Sheffield: nothing can be fouler probably than the state of the water at Sheffield, whereas if you go down to Doncaster the water is supplied by the waterworks, and is actually drunk in the town. I do not, however, say that it is a desirable thing.

5077. How many miles is Doncaster below Sheffield?—About 20 miles.

5078. Is it a rapid running stream?—No, it is not rapid in summer. In point of fact it is controlled by the weirs set up for the navigation. But take the river Irwell leaving Manchester, receiving the Irk, the Matlock, and all the refuse of the manufacturing population for a great many miles; when it travels down only eight or nine miles to Warrington it is perfectly changed, it ceases, or nearly ceases, in that short distance to be an

offensive river. I do not say that it has become all that it ought to be by any means, because the distance is not sufficient, and the flow is not rapid enough. The river is canalized, which prevents its flowing with all the rapidity it ought to have.

5079. You remember, do you not, the original condition of the river at Leicester after receiving all the sewage of the town into it?—Yes, perfectly well. I happened to be the engineer at Loughborough and also at Leicester. I made the waterworks at Leicester, and I advised the sewage works at Loughborough, and I also was called in to design waterworks for Loughborough, and I had on those occasions to take particular notice of the state of the river at all times, both at Leicester and at Loughborough, Loughborough being about 12 miles below Leicester. At Leicester the water was as black as this ink. I do not mean to say that it was absolutely so thick, but looking at it in a mass it was as black as ink—nothing would live in it, and the smell was abominable,—but by the time it got to Loughborough it was entirely restored to its pristine condition. You could stand on the bridge there and see the fish swimming amongst the beautiful reedy and other plants growing in the water just as in the purest stream. You could see every pebble at the bottom. That is an instance of the effect of oxydization.

5080. The water has symptoms of returning purity, has it not, within four miles of Leicester?—Yes, but not to the same extent as at Loughborough. The water was perceptibly impure at the driest period of the year down as far as Barrow. It could be just perceived there, but at Loughborough it was perfectly restored.

5083. Having regard to the capacity of the Thames watershed to yield a sufficient supply for the metropolis, (and when this system or purification is completed, whether for the sake of removing prejudice or any other purpose, to get rid of filth at all events the water must be improved,) you are of opinion that there is no necessity to seek a supply of water from a distance from the metropolis?—Certainly not. You have very fine water surrounding London in all directions, and it only wants utilizing.

Mr. Beardmore, Engineer to the River Lee:—

3329. What is your opinion as to the quality of the water supplied from those sources for the uses of the public generally for sanitary and domestic purposes?—I think that with proper arrangement of reservoirs the quality may be faultless, always excepting the carbonate of lime, which I regret to see published every week as so many grains of impurity, being merely a solution of pure chalk in the water. It is called in the papers impurity, but setting aside that carbonate of lime you will never get a purer water. In fact the New River is as pure as Loch Katrine now very generally, and with reasonable arrangements you may have the water still purer.

Mr. Leach, Engineer to the Thames Conservancy Board:—

4289. It would of course greatly improve the river if that sewage and other contaminating matter were diverted?—It would improve the condition of the river, but I think that the contamination has been very much exaggerated. In those country towns there is no regular system of sewage generally. The majority of the houses drain into cesspools; and really there is no very large outfall in any case except at Windsor; there a more perfect system of drainage has been carried out, and there is a most offensive outfall.

4290. Still there must be a very large amount of ammonia flowing into the river notwithstanding the cesspools, because of the overflow which you must necessarily catch in the river. A cesspool is very soon filled, and though not filled with solid excreta still there is an overflow, and that must find its way into the river ultimately?—The ground absorbs a good deal of that. I have noticed the outfalls of some of the larger towns, such as Abingdon and Wallingford, and although they are unquestionably offensive, still there is not that volume which would be the case with a similar population in London.

4291. Is the volume of water in the river sufficient to deodorize it?—Yes, it very soon loses any contamination.

4292. Take Windsor for example, where there is a discharge of a considerable amount of sewage out of their drains, have you observed the condition of the river at the point of discharge and also a few miles down?—Yes, I have.

4293. How soon in your observation is the effect of sewage destroyed by its flow and admixture with the water?—At Windsor it is discharged into a most unfavourable point in the river, where there is little or no stream at ordinary times. At times of flood of course there is more stream, but usually there is very little stream there, and the matter which is passed out of the drain floats about in the river there to a very great and very disgusting extent.

4294. Is there an eddy there, or what?—No, there is a weir just immediately below, which deadens the stream sufficiently to deprive it of the force required to take what is floating away. Two miles or even a mile below that I could see no traces whatever of the sewage.

4295. Was it all broken up and destroyed?—Yes, and taken by fish, and so on.

4296. Is it the habit of fish to take up matters of that kind?—Yes, you generally see persons fishing close to the outlet of a drain. I think that the operation of the Act of 1866, which prohibits the discharge of sewage into the river, will have a very beneficial effect. If some such provision had not been passed I can quite understand that as the system of waterclosets was extended and a more perfect system of drainage was carried out, the river would rapidly become much more contaminated; but the powers contained in that Act will, I hope, put an effectual stop to the pollution of the river.

Mr. Simpson:—

4625. With regard to the effect of the London water, which your companies supply, upon the health of the population, do you consider it an unwholesome water?—No, decidedly not. I believe the water to be as wholesome as any water that we can obtain.

4627. Are we to understand that you have heard nothing or seen any returns that would lead you to believe that the water supplied to London is bad in quality and injurious to health?—I certainly have not. I believe that a great deal of what has been stated upon that point is merely assertion without inquiry. I have been in the habit of being consulted by towns not only in England but on the Continent, and I doubt whether any city in Europe is better supplied than the metropolis either in quantity or quality.

Mr. Quick:—

6009. The quality of the water you say is good?—It is very good indeed for all purposes, not only for domestic purposes but for manufacturing purposes. Brewers and tanners, and those people who use large quantities of water for trade, all prefer the Thames water to any other water that they can get.

The following remarks by Mr. Pole (Appendix O.) also bear on this question:—

Below Lechlade the Thames is canalized, the water being held up by locks, weirs, and sluices at intervals, forming successive ponds.

There appears to be no traffic worth speaking of in a large portion of this navigation; but the weirs have, I have no doubt, a very beneficial influence on the quality of the water, as its flow over them causes great agitation and aëration, and so must promote considerably the breaking up and oxydation of the organic matter. This fact I think ought to receive more consideration than hitherto in the discussion of the general economy of the river.

The towns of Cirencester, Cricklade, Lechlade, Fairford, Northleach, Swindon, Highworth, and some other small places, lie in the basin above this point, but as no systematic drainage by sewers (except to a small extent at Cirencester) is carried out in any of them, I think it may be said that the only contamination of importance received by the water is from the tilled land. And from the absorbent nature of the ground over nearly the whole of the district, this will naturally be much less than in places where the waters flow over retentive soils.

Analyses of the Waters of the Thames and its Tributaries made for the Commission.

186. The analyses, by Drs. Frankland and Odling, of the samples collected by Mr. Pole (see Appendices O, and A X 1 and 2) show the difference in the quality of the water of the Thames, in different parts of its course, and of its principal tributaries, together with the character of the water of some of the main springs feeding these rivers. The facts obtained are important, although we see reason to differ from some of the conclusions which one of the chemists has drawn from them.

Dr. Frankland adds to these analyses the following remarks of his own:—

The conclusions arrived at from the foregoing investigation of the waters of the Thames basin may be thus summarised:—

1. The head waters of the Thames and the waters from chalk wells and springs in the Thames valley contain but a very small proportion of organic matter, which is, however, highly nitrogenized. They are very hard, and, with one exception (the Caterham well water), exhibit a high previous sewage contamination. Although markedly superior to the river waters at present supplied for domestic purposes to the metropolis, they are much inferior to the Welsh and Cumberland samples.

2. All the feeders of the Thames (exclusive of the head waters) which have been examined, are, without exception, ill adapted if not utterly unfit for domestic purposes. They are all decidedly inferior to the Thames itself at Hampton, and consequently none of them could be substituted with advantage for any portion of the present metropolitan supply.

3. The head waters of the Thames are polluted by sewage or manure matters soon after leaving their sources, and on reaching Lechlade are contaminated even to a greater extent than the Thames water delivered in London.

4. The precise effect of the flow of a stream, in purifying the water from sewage or manure matters, cannot be clearly ascertained from the foregoing investigation; but the analytical results demonstrate that at no part of its course does the Thames become freed from the soluble animal organic matters with which it is contaminated, although the total amount of these matters becomes diminished as the stream pursues its course.

5. After leaving its head springs, the water of the Thames is purer and better adapted for domestic purposes at Hampton than at any other point in its course.

6. Irrigation, properly carried out, purifies sewage to a great extent, but not sufficiently to render it admissible into potable water without danger; the risk arising not only from the considerable amount of animal organic matters which the effluent water still retains in solution, but also from the absence of any guarantee for the removal of the germs or other noxious suspended matters which are frequently present in sewage.

Dr. Odling adds as follows:—

It may assist the Commission, in interpreting the results of our analyses, to have their attention drawn to the following points:—

1. That unoxydized nitrogen, or nitrogen in the forms of organic substance and ammonia, is the characteristic constituent of animal excretions; and that if the entire daily excretions of the 800,000 persons living above the Thames at Hampton were added at once to 800,000,000 gallons of water, or the daily quantity of water flowing past Hampton (*i.e.*, if the excretions of one average person were added to 1,000 gallons of water), they would give to the filtered water a proportion of unoxydized nitrogen amounting to ·3 part in 100,000 parts.

2. That whereas, in fresh animal excretions almost the whole of the nitrogen exists in the form of organic substance, and but a minute proportion in the form of ammonia, in ordinary town sewage about four-fifths of the dissolved nitrogen has become changed into ammonia, only one-fifth remaining in the form of organic substance; so that if the sewage of 800,000 persons were included at once in 800,000,000 gallons of water, it would give to the filtered water a proportion of nitrogen in the form of ammonia amounting to ·24 part, and a proportion of nitrogen in the form of organic substance amounting to ·06 part in 100,000 parts.

3. That according to the tables of results, the excess of unoxydized nitrogen in Thames water at Hampton, above that in the Head Springs water, is ·015 part, and the entire amount of unoxydized nitrogen in the water at Hampton, but ·024 part in 100,000, the two waters being alike free from ammonia; whilst, of feeders, &c., of the Thames draining sparsely populated districts, the quantity of unoxydized nitrogen amounts in the Kennet above Hungerford, to ·034 part, including ·003 of ammonia; in the Thames below Lechlade, to ·036 part, including ·003 of ammonia; in the stream from Bagshot sands, to ·046 part, including ·003 of ammonia; in the Wey above Godalming, to ·066 part, including ·001 of ammonia; and in the Thame, to ·075 part, including ·001 of ammonia, in 100,000 parts of water.

187. An examination of these analyses shows:—

	Parts.
1. That the solid residue in 100,000 parts of the *waters of the Thames* and of its *tributaries* in the Oolitic and Chalk area varies from	25·58 to 32·95
And from its *tributaries* flowing through or from the Bagshot and Lower Greensand districts from	7·05 to 18·10
2. That the proportion of *lime* (as carbonate of lime chiefly) in this residue varies in the one case from	11· to 15·03
And in the other from	·68 to 5·73
3. That the *springs* in the Chalk and Oolitic districts contain of solid residue from	28·25 to 32·36
4. That the *lime* in these different springs is in nearly equal quantities, varying only from	14·00 to 14·50
5. That the quantity of sulphuric acid (in combination chiefly as *sulphate of lime*) varies in the tributaries of the Chalk district from	·49 to ·54
Ditto, ditto, Oolitic limestone district from	1·62 to ?
Ditto, ditto, clay and mixed districts from	3·68 to 4·28

Of other inorganic substances the quantities are small.

In the whole course of the Thames, from Lechlade to Hampton, the only resulting difference in the quantity of solid residue is ·56, showing a decrease of from 28·63 to 27·87. Part of the lime present in the springs is precipitated, apparently by exposure to river flow, both in the Thames and the Lee, showing a reduction of from about 14·25 to about 11·50 in the 100,000 parts of water.

188. There are great anomalies in the quantities of nitrites and nitrates present in the springs and in the rivers in different parts of their course. All the springs hitherto examined, whether in the chalk or oolitic districts, contain more of these salts than the river waters do, as estimated by the quantity of nitrogen in combination with them, which varies from ·358 to ·422. From ·358, which is the quantity in the head springs of the Thames, it decreases rapidly to ·157 at Lechlade. It rises again to ·277 below Oxford, decreases to ·245 at Abingdon; is ·205 above and ·211 below Windsor, and falls to ·196 at Hampton. Some effect is no doubt partly due to the addition of sewage matter as the river passes these towns, and we had hoped to obtain a measure of the extent of conversion of organic matter into innocuous nitrates and nitrites by the plan adopted of testing the water before and after it had passed the principal towns on the banks of the river; but the change effected by other causes, especially by the influx of the tributaries, is so much greater, that it becomes difficult, or rather impossible, at present to apportion effects to the relative causes. Thus the high figure below Oxford is in greater part accounted for by that of the Cherwell, which, two miles above Oxford, gave ·264, while again the Thames proper had risen from ·157 at Lechlade to ·218 above Oxford, influenced possibly by the smaller tributaries it had received in its 27 miles flow. At Caversham, above Reading, the quantity had again increased to ·286, whereas just below Reading, after receiving the drainage of this town, it fell to ·148; this arises evidently from the influx of the Kennet, which a little above Reading contains only ·029, while nearer its supply springs above Hungerford this tributary gives ·113. The Thame—the hardest and worst of the tributary waters—contained only the small amount of ·080 of nitrates. Again, the Thames at Hampton is affected on the one hand by the Colne with ·302, and the Wey with only ·090.

It would appear, therefore, that the effect produced by the drainage of towns into the Thames is quite subordinate to the changes produced by the flow of the river, the effects of vegetation, and probably by the action of the mud and silt, which in some of the tributaries, where there is a larger proportion of argillaceous matter present, may have a more efficient action in separating the bases of the nitrates and nitrites. The Thame flows chiefly over argillaceous strata, and the Kennet just before reaching Reading receives the several small streams draining the London clay and Bagshot sands of the district. The Wey has a portion of its drainage from the same formations. The fluctuations in the quantity of nitrates seems to us inexplicable upon the hypothesis of their immediate dependence upon recent organic matter. We should be more disposed, looking at the exceptional quantity present above Reading, in the Colne and at other places where the rivers have been largely fed by springs from the chalk, to refer much of it to supplies furnished by these springs. This, however, requires investigation.

189. The organic matter in solution in the waters of the Thames through its 140 miles course exhibits the same general persistence, accompanied by similar though not parallel fluctuations to those of the inorganic matter and the nitrates. In this case, however, the conditions at starting are very different. The quantity of organic nitrogen, taking that as the test of undecomposed organic matter present in the springs, is at its minimum instead of the maximum shown by the nitrates. The following table shows some of the

results of the analyses made for the Commission by Dr. Frankland which bear on this point:

	Organic Nitrogen.	Organic Carbon.
Amwell Well (taking this water to represent the springs of the Lee)	·009	·076
Otter Spring, the Colne, near Watford	·012	·026
Croydon Well (taking this to represent the spring water of the Wandle)	·007	·040
Syreford and other large springs, forming the main sources of the Thames	·009	·014
By the time the Thames has reached Lechlade these quantities have increased to	·033	·133
And subject to a number of fluctuations they stand on the river reaching Hampton at	·024	·260

190. The effects of town drainage, and the diminution of the quantity of organic matter brought about by the flow of the river, are more apparent in these experiments, but are still far from striking. Thus the quantity of organic nitrogen has decreased from ·033 at Lechlade to ·028 in the Thames above Oxford: after passing Oxford it still stands at ·028, but that is accounted for by the junction of the Cherwell with only ·025 of organic nitrogen; at Abingdon it falls to ·026, rises to ·032 at Caversham, increases to ·049 just below Reading, decreases, 5 miles lower, to ·032, decreases to ·028 above Windsor, rises at Windsor to ·029, and then falls to ·027.

191. In a supplementary report, Dr. Frankland and Dr. Odling call attention to the important fact that "the Thames is chemically purer at Hampton than at any other part "of its course." They account for the reduced quantity of mineral constituents by the influx of the Wey at Weybridge, which, draining a tract of Lower Greensand, Bagshot sands, and London clay, brings down less carbonate of lime, as is rendered clear by the results of their analyses, which show the solid residue in each to be—

Thames at Staines.	Colne.	Wey.	Thames at Hampton.
31·40	32·14	18·10	29·90

of which the lime is in the proportion of—

12·63	13·78	5·73	11·85

The nitrates in the same way give a mean result. They remark, however, that the marked reduction of ·003 part of organic carbon and ·044 part of organic nitrogen in the Thames between Staines and Hampton finds no explanation from this series of analyses, and they attribute it to some exceptional cause, such, possibly, as the precipitation of organic matter, which they show may take place when calcareous waters—such as that of the Colne—are mixed with peaty water like that of the Wey. We would, however, observe that the diminution in the quantity of organic nitrogen in the Thames in the five miles below Reading by ordinary oxidation (for there is no influx of any tributary) is ·017 part, while the ·072 part in the Thame water at Dorchester leaves the Thames water at Caversham, after a flow of about 18 miles, at ·032.

192. The fluctuations in the quantity of nitrogenized organic matter, in summer and winter, which their analyses show to take place, are, however, more remarkable, and need further investigation. They are as follows:

	Filtered Thames Water just below the Weir at Staines.		Filtered Thames Water at Hampton.	
	May 2d.	Oct. 28th.	May 4th.	Oct. 28th.
Organic substances in 100,000 parts of each water:				
Organic nitrogen	·027	·097	·024	·057
„ carbon	·304	·304	·260	·263

Compared to these the slight changes in the quantities of organic nitrogen noted in the Thames water in different parts of its course, from samples taken during the months of April and May, are comparatively insignificant.

193. Although these analyses of the Thames waters will require repetition and extension before the exact value of all the facts can be determined, yet as they relate to the river at one season they may be accepted as relatively correct, and they are sufficient to show at least not only the absence of any increase of objectionable matter in the river from

Lechlade to Hampton, but that the variations in the quality which commence at Lechlade, after showing several temporary changes in many parts of the river's course, fall at Hampton in general to a point as low as at Lechlade, and in one respect, viz., the organic nitrogen, to a point even lower.

It is necessary to remark that the river waters were filtered before analysis, but not the spring waters, which were only left to subside. This must be taken into consideration, as the effect of filtration on organic matter, to which reference is made elsewhere, is of great importance.

194. We cannot conclude this part of our Report without making a few observations on some of the inferences attached to the chemical analyses made for the Commission, as well as on some of the same character accompanying the monthly reports of the Registrar General, as they have been much disputed in the evidence, and as the authority these Reports carry is necessarily great. We refer especially to the interpretation put upon the presence of certain salts as indicating what has been termed "original sewage contamination," and on what are really impurities in water.

It is well known that decomposing organic matter is constantly giving rise to alkaline nitrites and nitrates. Dr. Frankland refers them, not simply to organic matter taken generally, but to sewage or manure matter especially; and the quantity of these salts is made the measure of the estimated "previous sewage contamination" of the different waters, for which a separate column is given. This seems to be an inference which can hardly be accepted. It would be perfectly correct if all the nitrogenized matter supplied to the Thames or other waters was, after conversion into nitrates or nitrites, retained in the water, and if also all these salts could be referred to sewage and manure matter solely. But such is not the case. All the analyses show how variable the quantity of these salts is in different parts of the river's course, and that the quantity present at any place is not so much dependent upon the sewage received as upon the removal which has been effected by vegetation and other causes, by the interference of tributaries, and by the addition from springs; so that, even supposing them to originate solely from animal origin, the residue affords no comparative results as to the amount of original contamination. The interfering causes are too numerous to allow us to assign any value to the remainder. We find it therefore difficult to understand the value of the meaning to be attached to "previous sewage contamination" if by that term it is supposed that we are able to recognize the amount of contamination produced in a river by the addition of the sewage of the towns by which it passes.

If the quantity also of nitrates varied in the inverse ratio of the organic nitrogen some more definite conclusion might be formed; but that is not generally the case. It appears that the sources most free from probable contamination, such as the springs forming the head waters of the Thames, contain in 100,000 parts of water, 3·260 parts of nitrates, whereas the Thames just below Lechlade contains only 1·270, and after experiencing various fluctuations as it flows by Oxford, Reading, and Windsor, still contains at Hampton only 1·640 or only one-half of that in the head springs of the river. The Kennet above Hungerford contains ·830, while just above Reading the quantity is 0. The chalk springs at Amwell give 3·740, while the East London Company's water at London shows 1·077. The water in Croydon well has 5·200, and the Wandle at Mitcham 3·704. The excess in the springs has been referred to manured lands, but this seems offered rather in explanation than as an ascertained fact.

Here the sources most free from possible contamination show the larger skeletons, whilst, after the known large additions of sewage matter made to the Thames at Oxford, Reading, Windsor, Henley, and other places, the proportional quantity of nitrates present in the river at Staines is no greater than at Oxford; so that without an *à priori* knowledge of the facts of the case, the analysis would have failed to indicate them. The Kennet, after flowing through Hungerford and Newbury, would seem by the column of "previous sewage contamination" to be as pure as the waters of Loch Katrine or Bala Lake; the river Lee, to become purer the nearer it comes to London; and the river Wandle, so far from suffering from the addition of the Croydon sewage from the Beddington meadows, would show to more advantage than the water at its source.

Nitrogenous compounds are, in fact, not peculiar to animal substances. They are present in a great number of plants. Their decomposition in either case may give rise to alkaline nitrates, and in the latter lead naturally to their introduction into the surface soil. Nitrites and nitrates are not only the result of the decomposition of sewage and other animal matter, but they are also constantly present in the soil and in springs. M. Boussingault, the distinguished French chemist, in his work on "Chimie Agricole," states that he tested for these salts in soils which were never manured, as in the soil of forests, as well as in soils which were slightly and much manured; that one kilogram

of earth from ground never manured, as for example that of the pine forest on the summit of the Liebfrauenberg hills, contained 0·0041 gramme of nitrates, another pine forest gave 0·0014, and the forest of Fontainbleau 0·0020; whilst a vineyard at Liebfrauenberg gave only 0·007, and a hop ground at Sauer 0·0018, both the latter being highly manured lands. Other cultivated lands gave larger quantities,—some very large. Much depends upon the fall of rain. The same able chemist shows also that nitrates are occasionally found in chalk, in some marls, faluns, and in gypsum, while springs equally free from known sources of contamination give very variable results. In lakes he generally found the quantity small. In some wells, on the other hand, he found as much as from half to one gramme per litre.

We cannot help therefore concluding that considerable sewage contamination may take place without indication of its presence by nitrites and nitrates, whilst in other cases these salts may be derived from vegetable matter and from springs which cannot be suspected of having been contaminated with true sewage matter. Their presence in moderate quantity does not indicate with certainty the presence of old sewage matter, nor does their absence prove freedom from such matter. At the same time, where an excess of these salts occurs, as in some wells, they should be regarded with suspicion, and form cause for immediate inquiry; for that they are generated largely by town sewage is indisputable.

Nor can we agree with some eminent authorities in looking at river water in a solely chemical point of view, and speaking of the presence of the 10 to 20 grains of mineral matter in the gallon as *impurities*. So, chemically speaking, they are, but as this seems to be almost a normal condition of river waters, we should not be disposed to consider this term an appropriate one to be applied to substances so constantly present in natural springs and streams.

And further, we cannot but consider it unphilosophical when, in addition to treating as "impurities" substances perfectly harmless even in much larger quantities, the minute quantities present in a gallon, or any other small measure of water, are multiplied by taking masses of water, such as the individual never has to deal with, and given to the public in figures so large as to tend to cause misconception, and perhaps unnecessary alarm in the minds of those not conversant with all the conditions of the case. It would be as just to speak of the small proportion of carbonic acid present in the atmosphere, equally in populous cities and in the Alps, as an impurity, and to startle those unacquainted with the subject by giving in some large figures the total quantity of that gas present in the atmosphere of London.

The question of main and vital importance is not the presence of a moderate quantity of mineral matter, which is of secondary importance, but refers to the presence of organic matter of an objectionable quality. Few waters are free from organic matter, but all organic matter is not objectionable in small quantities.

It is contended, and no doubt with truth, knowing beforehand the probabilities of the case, that although the soft waters of the mountainous districts of England and Wales contain as much organic matter as the Thames water, there is an essential difference in its quality. Still the evidence is by no means conclusive even on this point. Whilst on the one hand there is clearly far less objectionable matter introduced into the former, on the other hand the remarkable power of oxydation possessed by running water, admitted more or less by all chemists, so destroys and removes organic matter that the water regains in a great measure its original purity, either unassisted or else further aided by filtration. It is possible also that the deposition of carbonate of lime, which is known to take place in rivers where the saturation has been in excess of a given quantity, may carry down with it, as it does in Clark's process, a certain quantity of organic matter. The singular fact also noticed by Dr. Frankland and Dr. Odling, of the precipitation of nitrogenous organic matter by the influx of a more peaty water into the Thames is of great interest.

Where a minute quantity only of organic matter escapes destruction, it would seem that chemistry is not yet sufficiently advanced to pronounce authoritatively as to its exact quality and value, and with microscopic living organisms, especially, chemistry is incompetent to deal, and other modes of examination are needed.

Where the organic matter is present in quantities sufficient to diminish the free oxygen in the water, or to tend to putrefactive decomposition, danger is to be apprehended, and considering the nature and scale of the experiment now about to be made with respect to the disposal of the sewage of towns, too much care and watchfulness cannot be exercised in face of the risk which any neglect or oversight might give rise to.

Whatever may be our difference of opinion with respect to some of the conclusions, we

cannot place too high a value on the independent analyses of the water supplied to London, published monthly in the comprehensive and important Reports of the Registrar General.

B.—ON THE FUTURE INFLUENCES LIKELY TO AFFECT THE QUALITY OF THE WATER FROM THE BASIN OF THE THAMES.

195. We must look forward to the prospect of a probable increase of the quantity of sewage coming from the towns, and which if allowed to be poured into the river and its tributaries, would no doubt have a serious effect on the quality of the London supply.

The Chemical Commission of 1851 say:—

"The contamination by sewerage, however, cannot fail to become considerable and offensive with the increase of population, and the more efficient and general drainage of towns. And it appears to be only a question of time, when the sense of this violation of the river purity will decide the public mind to the entire abandonment of the Thames as a source of supply, unless indeed artificial means of purification be devised in the meantime and applied."

And again:—

"The removal of the nuisance complained of, however, can never be complete, but only partial. The contamination from navigation and the river population must be increasing rather than otherwise; while gas-works and other indispensable chemical manufactories, which at present pour their refuse products directly into the river, would necessarily continue to do so, as these products are often of a kind not admissible into ordinary sewers."

196. This question, however, has been grappled with by the Rivers Pollution Commission, who in their report on the Thames, March 1866, have treated at considerable length the subject of the purification of the river, not only from house and town sewage, but also from the refuse of manufactories and other pollutions.

In regard to the former they came to a conclusion expressed as follows:—

"That from experiments conducted under the Sewage Commission, and evidence taken on the subject of sewage utilization, and also from our own inspections and investigations, and from the evidence appended to this report, we believe that town and house sewage may be so utilized on land as to preserve the river from the danger of pollution."

They proposed certain changes in the governing body in whom was vested the conservancy of the river, and added the following recommendations:—

"That, after the lapse of a period to be allowed for the alteration of existing arrangements, it be made unlawful for any sewage, unless the same has been passed over land so as to become purified, or for any injurious refuse from paper-mills, tanneries, and other works, to be cast into the Thames between Cricklade and the commencement of the metropolitan sewerage system, and that any person offending in this respect be made liable to penalties to be recovered summarily.

"That it be made incumbent upon the conservators to see to the enforcement of the above prohibitions against pollution of the river, and that for this purpose power be given to them to visit and inspect works, and, after due notice, to close the outlets of sewers, drains, and discharge-pipes into the river within the limits described in the last preceding recommendation.

"That, subject to proper safeguards to prevent abuse, powers be given to local authorities to take land compulsorily for the purpose of sewage irrigation, to an extent not exceeding one acre for every 50 persons whose sewage is to be applied.

"That the conservators be empowered to levy upon all waterworks, taking water for domestic or trade purposes from the River Thames, a rental in proportion to the volume abstracted; the maximum of such rental to be named by Parliament."

197. In consequence of these recommendations an Act was passed in August of the same year (29 & 30 Vict. cap. 89), intituled "An Act for vesting in the Conservators of "the River Thames the Conservancy of the Thames and Isis from Staines, in the county "of Middlesex, to Cricklade, in the county of Wilts, and for other purposes connected "therewith." It altered the constitution of the existing Conservancy Board of the Thames, and considerably enlarged their powers and the extent of their jurisdiction.

The following clauses relate to the improvements affecting the quality of the water of the river:—

"52. The Conservators shall cause the surface of the Thames to be (as far as is reasonably practicable) effectually scavenged, in order to the removal therefrom of substances liable to putrefaction.

"63. From and after the passing of this Act it shall not be lawful for any person to do any of the following things, namely,—

"(1.) To open into the Thames any sewer, drain, pipe, or channel with intent or in order thereby to provide for the flow or passage of sewage, or of any other offensive or injurious matter:

"(2.) To cause or, without lawful excuse, (the proof whereof shall lie on the person accused,) to suffer any sewage or any matter aforesaid to flow or pass into the Thames down or through any sewer, drain, pipe, or channel not at the passing of this Act used for that purpose:

"(3.) To open into any river, stream, cut, dock, canal, or watercourse communicating with the Thames at any point within three miles of the Thames, measured in a direct line therefrom, any sewer, drain, pipe, or channel with intent or in order thereby to provide for the flow or passage of sewage or of any matter aforesaid in such manner that the same will be carried or be likely to be carried by, through, or out of that river, stream, cut, dock, canal, or watercourse into the Thames:

'(4.) To cause or, without lawful excuse, (the proof whereof shall lie on the person accused,) to suffer any sewage or any matter aforesaid to flow or pass into any such river, stream, cut, dock, canal, or watercourse at any point within the distance aforesaid down or through any sewer, drain, pipe, or channel not at the passing of this Act used for that purpose, in such manner that the same will be carried or be likely to be carried by, through, or out of that river, stream, cut, dock, canal, or watercourse into the Thames:

"If any person does any act or thing in contravention of this enactment he shall for every such offence be liable on summary conviction to a penalty not exceeding one hundred pounds, and to a further penalty not exceeding fifty pounds for every day during which the offence is continued after the day on which the first penalty is incurred.

"64. Whenever any sewage or any other offensive or injurious matter is caused or suffered to flow or pass into the Thames, or is caused or suffered to flow or pass into any river, stream, cut, dock, canal, or watercourse communicating with the Thames, at any point within three miles of the Thames, measured in a direct line therefrom, in such manner that the same is carried or is likely to be carried into the Thames, then and in every such case, whether any such sewage or other matter aforesaid had or had not been so caused or suffered to flow or pass before the passing of this Act, the Conservators within a reasonable time after knowledge of the fact shall and they are hereby required to give notice in writing under their common seal to the person or body causing or suffering the same so to flow or pass, to the effect that they require him or them to discontinue the flow or passage thereof as aforesaid within a time to be specified in the notice, not being in any case less than twelve months or more than three years; provided that the Conservators may, if they think fit, at any time and from time to time extend the time specified in the notice by another notice in writing under their common seal; but nothing in this section shall authorize the Conservators, until the expiration of six months after the passing of this Act, to give to the owner or occupier of any mill or work a notice requiring him to discontinue the flow or passage as aforesaid of any liquid matter produced or used in the manufacture of paper or in any process incidental thereto."

"65. Subject to the provisions of this Act, any person to whom any such notice is given by the Conservators shall, notwithstanding anything in any other Act, within the time allowed by the notice, discontinue the flow or passage of the sewage or other offensive or injurious matter to which the notice refers, and if any person fails to do so he shall be guilty of a misdemeanor, and shall be liable, on summary conviction thereof before two or more justices, or on conviction thereof on indictment, to a penalty not exceeding one hundred pounds, and to a further penalty not exceeding fifty pounds for every day during which the offence is continued after the day on which the first penalty is incurred."

In consideration of the improved quality of the water which it was assumed would result from these measures, the five metropolitan water companies drawing water from the river agreed and were bound by clauses 59 to 61 of the Act to pay to the Conservancy Board, each the sum of 1,000*l.* per annum, in addition to certain sums previously agreed to be paid by some of them.

198. We have had before us the chairman, Mr. Thorpe, the secretary, Captain Burstal, and the engineer, Mr. Leach, of the Conservancy Board, and we learn from them that they have served the notices required by the Act, on all the local authorities, from Oxford downwards, to discontinue discharging their sewage into the river.

We are not aware what the result of these notices has been; probably sufficient time has not elapsed to carry out the works necessary, but we presume we may take it for granted that the provisions of the Act will be duly enforced, and that if any difficulties should arise in doing so the subject will receive the attention of the Legislature.

199. Presuming, therefore, the sewage to be used upon the land, it only remains to inquire what amount of benefit may be expected from this measure. It must be borne in mind that the use of liquid sewage for irrigation does not entirely intercept it; for after deducting a certain loss by evaporation and absorption during the irrigation process, the remainder must still flow off into the streams; and hence the question becomes, to what extent will this latter portion be improved in quality over its original state of simple sewage?

200. This question presented itself to the Conservancy Board, and they referred it to three eminent chemists, Drs. Letheby, Frankland, and Odling, desiring them to report— 6851 et seq.

"Whether fluid which has been mixed with sewage can be so purified as to be admissible into the river Thames, and if so, in what manner it may be done; and to fix a standard of purity."

The report given in answer to this question is printed in Captain Burstal's second evidence. The referees examined carefully the application of the sewage irrigation systems

in use at Croydon, Rugby, Carlisle, Worthing, Leicester, and Hertford, and give their opinion that if the process is performed under certain conditions, the defæcated fluid is remarkably improved in quality and may be safely discharged into any running stream. Dr. Frankland, however, adds an opinion as follows:—

"P.S.—The conditions under which fluid which has been contaminated with sewage may be admitted into the Thames, as prescribed in the foregoing report, will, I have every reason to believe, preserve the river from being offensive to the inhabitants upon its banks; but, whilst thus far agreeing with my colleagues, I wish it to be distinctly understood that, in my opinion, such fluid can only be safely admissible into the Thames on condition that the water is not afterwards used for domestic purposes. Neither by the processes of purification mentioned above, nor by any others of a practical nature, at present known, can water which has once been contaminated with sewage be, in my opinion, again rendered safe for human use."

The Board referred Dr. Frankland's opinion to the two other chemists, who expressed their dissent from it.

Dr. Letheby says:—

"In reply to your letter of the 5th instant, I have to state that I cannot at all agree with Dr. Frankland that the water of the Thames, after receiving defæcated sewage water, is unfit for domestic use; for after a large practical acquaintance with the subject as it is observed in the principal streams and rivers of England, I have arrived at a very decided conclusion that sewage when it is mixed with about 20 times its volume of running water and has flowed a distance of 10 or 12 miles, is absolutely destroyed; the agents of destruction being infusorial animals, aquatic plants and fish, and chemical oxydation.

"I have stated this in evidence before Parliamentary Committees and Royal Commissions, and I am satisfied that the opinion is well founded."

Dr. Odling says:—

"From many considerations, and especially from the fact that the undefæcated sewage, &c., discharged into the Thames above the source of the present water supply is not recognizable in the water at present supplied, I am decidedly of opinion that the water of the Thames will not be rendered unfit for human use by receiving sewage matter defæcated in the manner described, unless the proportion of such defæcated sewage should become much larger than there is any reason to anticipate."

201. Many able witnesses have given us evidence on this subject.

Mr. Simon says:—

2817. But assuming that the powers given to the Commissioners of the River Thames Conservancy are fully carried out, which amount to an absolute prohibition as to the towns drawing their sewage directly into the Thames, would not that, in your opinion, be an immense advantage in purifying the present supply of London, which is taken now above Teddington lock?—Yes, it would be a very great gain.

2818. Supposing that the prohibition were extended to all sewage going directly into the river at any part of it, and that under the powers which are given to the Thames Conservancy Board, they compelled the towns to distribute their sewage for the purposes of irrigating the land, and consequently that all the water falling on the surface merely came into the river after having passed through the soil, do you think that in that case the Thames water taken above Teddington lock would still be polluted, or should you consider it to be practically free from pollution?—Assuming a sufficient thickness of soil, I should so consider it.

2819. Can you form any opinion at all in that case as to whether the water taken above Teddington lock would still be impure and unwholesome, supposing, for instance, it had travelled exposed to the atmosphere for 15 or 20 miles of river?—I should think it quite a safe water as regards the danger that we are speaking of.

2839. Supposing that those upper towns are driven to deodorize their sewage, or to apply it for irrigation to the land, would the water that must pass off ultimately into the river be sufficiently purified, do you think, so as not to affect the river prejudicially?—A speculative answer is not worth much upon this subject, and I can only give a speculative answer at present. I think it very likely that the water would be harmless, but possibly the result might show that the water could not be deemed quite safe.

Dr. Parkes says:—

3230. Assuming that under the powers of the Act of last session all that sewage will be diverted in the first instance from the Thames and used upon land, would you not consider that the result would be that it would be very much purified beyond what it is at the present moment?—I have no doubt of that at all, but it is impossible to say what the amount of purification would be, because I do not know what the conditions would be of the irrigation of land in proximity to the river, or the amount of water which would pass through the land.

3231. All that would be laid upon the chalk and oolites would be almost entirely absorbed by the land, would it not?—Yes.

3232. But where the sewage is laid upon the clay it would come off more rapidly?—Yes.

3233. Do you think that if that plan were carried out there would be still an impurity in that water sufficient for you to say that it ought not to be used?—I should feel very great difficulty in answering that question.

3234. You seem to say now that from Dr. Frankland's analysis it is what you would call a suspicious water?—I should say so, because there has been certainly organic matter in it derived from sewage, and though that has been oxydized to a considerable extent, still, as showing previous impregnation, and as indicating that there might be a further passage of sewage into the water, and the possibility of a less degree of oxydation at certain times, I should call it a suspicious water.

3235. Then until that purification has taken place which is now in progress, and the water is analysed afterwards, you think that no opinion could be formed upon that point?—I should like to know whether it would be effectual or not in completely diverting the sewage from the Thames, and I should hardly think it possible to form any opinion upon that point.

Dr. Letheby says:—

3891. "I think that none of the sewage discharged into the Thames can at the present moment be discovered at Hampton, but nevertheless it is very possible that there may be a still further improvement of the Thames water

by the adoption of these measures. Certainly there will be an improvement in this manner, that if the discharge of the sewage into the Thames were to go on increasing during the next 20 or 30 years, as it has been during the last 20 or 30, we should then probably have such an excess of sewage in the water of the Thames as would render it very unwholesome."

Dr. Frankland gives evidence as follows:—

6376. Supposing the sewage were diverted from the Thames in pursuance of the existing law as carried out by the Thames Conservancy Board, would your objections be removed with regard to the Thames water being suitable for the supply of London?—They would be removed so far as the actual sewage was concerned. I should still object, although in a mitigated degree, to the drainage from cultivated land flowing into the Thames. But in speaking of the diversion of the sewage from such towns as Oxford and Windsor, the mere diversion of that sewage so as to throw it upon land, and then allow it to drain or to make its way into the Thames, would not overcome my objection to the water on the ground of the sewage, because I do not think that sewage which has been merely passed over land, or even through land, can be safely allowed to mix with water that is to be employed for domestic use.

6377. Then your gathering ground for the supply of large towns must necessarily be very limited if that view prevailed, that it should pass over no cultivated land, and that the smallest particle of sewage makes it unsuitable for domestic purposes?—If you have no choice of water, of course it would be much preferable to drink water that was contaminated only from the drainage from manured land, as compared with that which was contaminated directly by sewage. But sewage that has been allowed to flow over land, and which perhaps does not sink into the land at all, would, I should think, be much more objectionable than the water drainage from cultivated land, and which is manured principally from animal as distinguished from human manure.

6378. In the case of the 250 acres of land at Croydon upon which the sewage of that town is spread, the water running off into the Wandle is to the eye perfectly pure; have you ever examined any of that water to ascertain whether there is still held in solution that which is prejudicial to human health?—I have examined that particular water which you have mentioned, and also a number of other similar waters running off land upon which sewage has been placed. Those examinations have been recently made by Dr. Odling and Dr. Letheby and myself for the Board of Conservators of the Thames, and I may say that the substantial result, at least what I myself would say was the substantial result, of those examinations is, that about four-fifths of the sewage matter is destroyed under favourable circumstances, but that is all you can calculate upon. So that if you were to have all the sewage which is at present poured in an unmitigated form into the Thames distributed over the land as it is done at Croydon, you would reduce the amount of contamination of the Thames to one-fifth of what it is at present. In other words, if the population increased to five times its present amount, in the Thames basin the contamination would be as great as it is at the present day, after the sewage had passed over the land.

6396. Assuming that the Act of Parliament which was passed last session for preventing the pollution of the river Thames is efficiently carried out, and that no sewage is directly discharged into the river, and assuming also that those companies adopt proper modes of filtration, would not this specially objectionable case be to a great extent met?—With regard to the muddiness of the water, it would completely, but not with regard to the wholesomeness completely. The unwholesomeness of the water would doubtless be mitigated by otherwise disposing of the sewage, or rather, I should say, by passing the sewage over the land before its admission into the Thames; but I do not think that even after that such a proportion of sewage would be innocuous when admitted into the Thames.

Dr. Odling says:—

6443. But are you of opinion that, supposing the Act of last year were faithfully carried out, and the sewage were intercepted from the river Thames, the water on the whole would be a suitable water for the supply of London for domestic purposes?—Yes, I am.

Sir Benjamin Brodie says:—

6992. Are you prepared to express an opinion on the result of the application of sewage to the land, the water being afterwards discharged into a river, whether it would or would not be injurious to health after its filtration through the soil?—No; I think here again the same obscurity prevails, only to a less extent. I think it is certain that the sewage water must be benefited very materially indeed by being filtered through the land, and I have that opinion because I know that in the porous material of the land the processes of oxydization which destroy the injurious sewage matter go on much more rapidly and efficiently than they do otherwise, and not only that, but that the land operates as a filter and stops, mechanically, a large portion of the solid injurious matter of the sewage; but if you ask me whether the water that runs out from the land, although it may be bright and clear, is a good beverage, I do not know how we are to answer that question except by giving the water to human beings to drink, and by long observation of its effects.

6993. Then, although the process of filtration may catch and retain all that is held in mechanical suspension, still in your judgment there may be elements passing off in solution that might be injurious to health?—I think there may be, certainly, and not only in solution, but even not in solution; I mean by that that there may be even solid matters, organic germs, which would be so small that they would pass through the filtering material employed.

6994. And which might be unobservable to the eye?—Unobservable altogether to the senses, and yet which might be extremely detrimental to the health; but here again you cannot say that they are detrimental to the health, you can only say that they may be so.

7039. What course do you consider the most efficacious one to get rid of sewage contamination from the towns on the river?—The best is not to put the sewage with the river at all, that is the best answer I can give, and, indeed, that is really the only course by which you can be certain that you have not got it in. I certainly do think it a very good thing to employ the processes used for the filtration and destruction of sewage, and they are *pro tanto* beneficial. They really help the matter a good deal, but I do not think that they are entirely effectual. There is no known process that I am aware of for, on a large, scale destroying the injurious qualities of sewage.

7040. By throwing it upon the land you absolutely get rid of a large portion of the sewage, and what is left is somewhat improved?—Very greatly improved, but I should not like to take a glass of water and drink it from just the spot where it went into the river, still less to make it one's daily and habitual beverage.

Dr. Angus Smith says:—

7204. Is it your opinion that after the application of sewage to the land the water filtered off and running into the river would be harmless?—If the land or the filter is not overburdened with sewage, that is to say, if no more is allowed to pass through than can be properly oxydized, then complete purification must take place.

7206. Then, as a rule, are you of opinion that it would be safe to apply sewage to land and allow the water to run off into a river which is the main source of supply to a town for domestic purposes?—It is certainly safe to apply some. I am not able at this moment to say how much. I am not able to say, considering the new plans of irrigation proposed, that it would be proper to load the neighbourhood of a large town with sewage, and collect the water from it and use it for the town. I am inclined to think that it would not be safe; but in a thinly populated agricultural country I think we have no reason to believe that any danger can occur. . . . . I therefore conclude that it is a question of quantity, how much sewage can be put upon the land.

Mr. Hawksley says:—

5074. Are you aware that the Thames Conservancy Board are now clothed with power to call upon all the local authorities on the banks of the river, up to and including Oxford, to divert their sewage and other polluting matter from finding its way into the river?—Yes.

5075. Of course the river would be greatly improved if that principle were adopted uniformly up the river?—The river would be very much improved near the towns themselves, but at considerable distances from the towns it would have no effect whatever, because all those matters are exceedingly decomposable in the presence of oxygen and become decomposed entirely by oxydization. There is no such thing as a particle of fæcal matter put into the Thames at Oxford finding its way down to Hampton Court. It is all burnt up in fact by the combustion set up by the oxygen.

Mr. Greaves says:—

5169. Have you seen the report which has just been issued out from the River Pollution Commissioners?—Yes, I have.

5170. They recommend that the same course should be followed in the Lee as had been adopted by Act of Parliament with regard to the Thames, but giving power to a new body to prevent the pollution of the Lee for the future. If that were carried out do you think it would add to the good quality of your water?—I have not the least doubt that it would.

202. During the inquiry our attention had been called to the improvement made in the water of the river Wandle by the sewage irrigation practised at Croydon, and as this example of the process was so accessible, we requested Mr. Pole, when collecting the samples of water from various parts of the Thames basin, to visit these works and to take specimens of the sewage before and after defæcation, and to submit them to Drs. Frankland and Odling for analysis. Mr. Pole's report will be found in Appendix O; he gives a general description of the process, and adds—

When I saw the system at work on the 11th May, although the sewage was foul and dirty when it went on to the land, the water running off was quite bright and clear, without any appearance of foul deposit in the channel. I noticed several fine trout in the river, near the point of discharge, as well as in other places farther down.

It is worthy of remark that the plan here adopted, of allowing the sewage to travel slowly over the land, in constant agitation among the blades and stalks of the vegetation, appears to me peculiarly favourable for the oxydation of the impurities by the action of the atmosphere, which I have no doubt powerfully aids the purifying action by vegetable absorption.

The report of the chemists will be found in Appendices A. X. (1 and 2); it shows that in the diluted condition in which the Croydon sewage is applied to the land, it contains only 11·6 grains more of solid matter (or 43·6 parts in 100,000 parts evaporated to dryness) than the well water of Croydon. In this undecomposed sewage water the ammonia has increased from ·001 to 2·191, and the organic nitrogen from ·007 to 1·156, whilst the nitrogen, as nitrites and nitrates, stands at ·000, whereas the Croydon well water contains ·551. After flowing off the land, the sewage contains only 34·4 parts per 100,000 of total solid residue, the ammonia being reduced to ·002, and the organic nitrogen to ·037, and the nitrogen, as nitrites and nitrates, has increased to ·317. At Mitcham, one mile lower down, the water of the Wandle contains only 31·0 parts of solid residue, or one part less than the Croydon well water, the ammonia has disappeared, the organic nitrogen has decreased to the extent of ·007, and the nitrogen, as nitrites and nitrates, has further increased to ·403. Dr. Frankland considers this amount of purification exceptional, as the quantity of solid impurity in the sewage water, as it flows off the land into the Wandle, would appear to vary according to the rainfall and the season of the year.

According to chemical analysis, the Wandle at Mitcham will contrast fairly with other river waters. The amount of contamination effected by the Croydon sewage, which, however, is weaker than London sewage, almost disappears after the river flow of three furlongs, and a mile lower down all excess of solid impurity has disappeared, the organic nitrogen only being in excess of the quantity existing in the Croydon well water. On the other hand it has to be observed that, notwithstanding the large and constant introduction of town sewage at Beddington, the nitrates and nitrites in the Wandle

at Mitcham are present in less quantities than in the Croydon well water, or than in many of the oolitic and chalk spring waters of the Thames basin. The following table gives some of the comparative results obtained by some of the analyses made for the Commission. It shows the condition of the Wandle 1½ mile below the place where it receives the Croydon sewage, as contrasted with the waters of the Thames and the Lee in places free from town sewage. The quantities are given for 100,000 parts of water.

	River Wandle at Mitcham.	Lee above Hertford.	Thames above Reading.
Total solid residuum	31·0	25·88	32·7
Ammonia	·000	·000	·001
Nitrogen as nitrates	·403	·246	·286
Organic nitrogen	·024	·025	·032
„ carbon	·099	·125	·291
Hardness before boiling	21·1	19·9	21·
Do. do. by Clark's test	14·8	13·9	14·7
Hardness after boiling	9·7	2·1	8·2
Do. do. by Clark's test	6·8	1·5	5·7

WATER FROM THE LEE VALLEY.

203. Our remarks hitherto have been directed principally to the quality of the water from the main stream of the Thames, but they apply also very generally to that from the River Lee.

204. The Rivers Pollution Commission, in their report on the Lee, dated May 1867, point out that the river, above the lowest intake of the water companies, is polluted by the sewage of Luton, Hertford, Ware, Bishop-Stortford, and many other places, as well as by manufacturing refuse of several kinds. In some towns attempts have been made to purify the sewage by different processes before its discharge into the river.

The New River are in the best position as to quality, as they escape the sewage of Hertford, Ware, and all below, and have moreover in their supply a large proportion of pure water received directly from the chalk.

The East London Company's intake is considerably lower, but still their supply is considered wholesome by the Rivers Commission, who report on it as follows:—

"With regard to the quality of the water, the water drawn at Ponder's End is not of course so pure as that taken by the New River Company higher up the stream, because the river in its course over the intervening space has received additional impurities from towns and places, as already detailed under the head of pollution, but this difference is greatly diminished by the fact that between Hertford and Ponder's End the Lee has been reinforced by a large accession of fresh water from the land springs which break out from the chalk into the bed of the river. The result is, as the analyses show, that the East London Waterworks Company are able to obtain a fair wholesome water. The company have gone to great expense to improve the water before it passes to their filter beds, by the construction (under statutory powers) of Catchwater Dyke to intercept sewage of certain towns above the intake, and to deliver it at a point below. In a bill now before Parliament the East London Waterworks Company proposed an extension of this system of intercepting sewers."

The Commission, however, came to the conclusion "that it is expedient that more "stringent measures be adopted to protect from pollution that portion of the metropolitan "water supply which is derived from the river Lee," and they made recommendations with that object.

205. In 1867 the Board of Trade directed an inquiry to be made, through Captain Tyler, into the severe outbreak of cholera which had taken place in 1866 in the east of London, and which had been ascribed principally, if not solely, to the bad quality of water supplied by the East London Waterworks Company. This case has been frequently mentioned in evidence before us, and it appears that by some faulty arrangements at the East London Works the foul waters of the lower part of the river Lee were admitted into the company's reservoirs.

The conclusions arrived at by Captain Tyler are expressed in the following extract from his Report:—

"The disease was, undoubtedly, very fatal during the visitation of last autumn in the metropolis, in the East London Company's field of water supply, and especially in the districts which drew principally from the Old Ford reservoir. There were, on the other hand, other localities, chiefly on high ground and of a better class, such as Stamford Hill, Leytonstone, Wanstead, Woodford, Buckhurst Hill, and Walthamstow, parts of which

are supplied exclusively from that reservoir, which were nearly or quite free from it. Silvertown and North Woolwich were exceptions, the former in the early part, the latter throughout the epidemic. All the houses in these latter places are on constant supply from the North London Company; and the disease was very fatal in certain localities near the East London Company's field of supply, where no water that they supplied could have been an exciting cause. The want of better drainage had, no doubt, much to do with the intensity and duration of the epidemic; but the mortality declined from the 1st and still more from the 9th of August; while the Metropolitan Board of Works commenced their pumping operations to divert sewage from the River Lee and the Limehouse Cut into the northern outfall sewer only on the 24th of August. The Lee must have been contaminated at Old Ford at an early period of the epidemic. The covered reservoirs at Old Ford may have received from the river at different times, as they were partially emptied, some of the poison; and the water supply of some of the districts drawn from those reservoirs may thus at different times have been to some extent infected. Considering this possibility of infection, and looking to the effects which were only too apparent in the general field of supply from Old Ford, a case of grave suspicion exists against the water supplied by the East London Company from Old Ford, and that proximity to absolute proof at which I hinted in commencing this subject has thus been nearly reached. But any poison so distributed would have been in a condition, if it were soluble in water, of considerable dilution, and I am not prepared on that account, as well as in consideration of the deplorable state in other respects of their district, to go so far as the memorialists in asserting that this water was 'the principal if not the sole cause of the fearful mortality from cholera.' I believe, however, that if, as is possible, choleraic poison did find its way into the company's mains, it must have passed directly from the River Lee into the closed reservoirs and I have no reason to believe that it was distributed in the water which was so improperly supplied to the district from the open reservoir."

But whatever may have been the connexion of the East London water with this outbreak of disease, it is clear that the evil arose from an accidental circumstance, and therefore affords no argument against the quality of the Lee water when taken under proper conditions, at the upper part of the river.

206. The House of Commons Committee of 1867, who devoted considerable attention to the Lee, state:—

"Your Committee having received scientific evidence of the present quality of the water supplied by the New River Company and the East London Company, are satisfied that, as far as chemical or other science affords the means of judging, the water is not only wholesome, but compares favourably with that supplied to other places."

The Committee noticed the pollution of the river, and after making some suggestions in addition to the conclusions of the Rivers Pollution Commission, they recommended that a bill should be introduced into Parliament to provide remedial measures.

207. This was done, and on the 31st July 1868 there was passed "An Act to make better "provision for the preservation and improvement of the River Lee and its tributaries, "and for other purposes" (31 & 32 Vict. cap. 154).

The provisions of this Act for excluding sewage and other contamination from the river are generally of the same nature as those enacted for the Thames; making, however, a special exception of the town of Luton, which is allowed to use a chemical purifying process instead of applying the sewage to the land.

WATER OF THE KENT COMPANY.

208. The water of this company is about four or five degrees harder than that of the Thames or the Lee, but in other respects it is fully equal to them, if not superior, on account of its smaller quantity of organic matter. Objection has been taken to the large quantity of nitrates and nitrites in this water, but we have already pointed out that this is not an unusual feature in the water of springs far removed from sources of pollution, as in those of the oolite at the head of the Thames valley, and the chalk.

FILTRATION.

209. It is absolutely essential to the good quality of the Thames water that it be effectually filtered. The Chemical Commission remarked in 1851 that the effect of ordinary filtration through sand was very decided on Thames water, as it appeared to be upon chalk waters in general. The river water, they remarked, could thus be easily obtained, under usual circumstances, entirely free from suspended solid matter or mechanical impurities. More modern experience seems to lead to the belief that filtration also acts, though probably in a way less understood, in improving the quality generally. The analyses in Appendix AG, by Messrs. Letheby, Odling, and Abel, which give the comparative qualities of filtered and unfiltered water, clearly show the advantage gained, as will be seen by the following extract:—

General Results.	Thames Companies.		New River.		East London.	
	Unfiltered.	Filtered.	Unfiltered.	Filtered.	Unfiltered.	Filtered.
	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
Dissolved matter, per gallon	20·825	19·479	22·402	21·550	24·940	24·360
Of which organic and other volatile matter	1·261	0·976	0·702	0·567	0·915	0·300
Suspended matter, per gallon	0·830	0·034	0·241	0·095	0·561	0·047
Of which organic and other volatile matter	0·173	0·005	0·033	0·014	0·045	0·023
Hardness before boiling (degrees)	14·4	13·3	15·5	13·5	14·4	14·0
„ after „ „	5·3	4·6	4·2	4·0	5·0	5·0
Dissolved gases, per gallon (cubic inches)	13·77	13·85	13·95	12·75	12·51	13·75
Dissolved oxygen, „ (grains)	0·796	0·825	0·906	0·906	0·891	0·752
Oxygen required to oxydise organic and other matter (grains)	0·146	0·134	0·115	0·069	0·090	0·095
Ammonia, per gallon (grains)	0·003	0·002	0·001	0·001	0·004	0·003

Mr. Wanklyn's letter, Appendix AK, says,—

"The water of the Thames at Hampton Court, where the companies draw their supply of water, is not very good, as it exists in the river; but after the filtration effected by *some* (but not all) of the companies, it becomes excellent, and in point of purity from organic nitrogenous matter is then fully equal to the water supplied to Manchester, Edinburgh, or Glasgow."

All chemists agree on the importance of filtration.

210. Filtration was made compulsory by the fourth clause of the Metropolis Water Act, which runs as follows:—

"IV. From and after the 31st day of December 1855, every company shall effectually filter all water supplied by them within the metropolis for domestic use before the same shall pass into the pipes for distribution, excepting any water which may be pumped from wells into a covered reservoir or aqueduct without exposure to the atmosphere, and which shall not be afterwards mixed with unfiltered water."

211. All the companies profess to comply with this provision, but the evidence shows that the filtration has been imperfectly carried out. In the Registrar General's annual summary for 1867 occurs this passage:—

"It is much to be regretted that the London waters are not more effectively filtered before distribution. Only on one occasion during the whole year have I obtained a transparent sample of water from the Southwark Company's main. The Grand Junction and Kent Company's waters were turbid four times out of 12, the Chelsea thrice, and the West Middlesex, Lambeth, and East London twice out of the 12 occasions when the samples were drawn for analysis."

In every succeeding monthly report the same complaint has arisen.

212. We call special attention to this neglect to comply with the provisions of the Act. The process of filtration presents no difficulties, all that is wanted being a sufficient area of filtering surface. There seems to be no efficient means of enforcing an observance of this provision of the Act, and the neglect of the companies to comply with it, notwithstanding the repeated attention drawn to the imperfect filtration, shows the necessity for some change in the system of supervision to which the supply of the metropolis is subjected.

GENERAL REMARKS BY THE COMMISSION ON THE QUALITY OF THE WATER FROM THE THAMES BASIN.

213. The evidence before us leads us to the conclusion that the Thames water has many good qualities which render it peculiarly suitable for the supply of the metropolis, and which give it, in some respects, a superiority over the soft waters usually obtained from high gathering grounds. When properly filtered it is clear, bright, colourless, agreeable, and palatable, and the amount and nature of its saline constituents are considered by many to contribute to its general acceptability for drinking. It is well aërated, has good keeping qualities, and is unusually safe as regards action on lead and iron.

On the Organic Impurities.

214. The evidence we have collected on this subject presents great diversities of opinion; but there is one result which, we think, is clearly deducible from the facts before us, namely, that in the present state of chemical science, analysis fails to discover,

in properly filtered Thames water, anything positively deleterious to health. Whatever may be the difference of opinion with respect to the time required for removal of all the objectionable organic matter, all the chemists agree that in Thames water taken from the present source and properly filtered, all such matter has disappeared, and that the resulting compounds, such as nitrates, &c., remaining therein are innocuous and harmless.

Having carefully considered all the information we have been able to collect, we see no evidence to lead us to believe that the water now supplied by the companies is not generally good and wholesome.

215. The only point raised against the Thames water on the ground of organic contamination is of a less positive character; it is said that water which has been once contaminated with sewage may still contain undecomposed organic matter, which, though inappreciable by the most delicate chemical tests, may still exercise prejudicial effects on the human system.

The strongest form of this objection has reference to some opinions now prevalent, that certain forms of disease, such as cholera and typhoid fever, are propagated by germs contained in excremental matter; and it is conceived possible that when matter of this kind once gets into streams, these germs may escape destruction and long preserve their dangerous character. It is said that no process is known by which such noxious material can be removed from water, and therefore it is argued that water which has at any time been contaminated by sewage is thenceforth unsuitable for domestic use.

These opinions have been advanced by many eminent men of science; they are worthy of respectful attention, and ought to operate as a constant stimulus to the most searching examination of the state of the water; to the improvement of the modes and means of scientific analysis; and to the diligent collection of medical data as to the effect of the waters upon the public health. But we cannot admit them as sufficiently well established to form any conclusive argument for abandoning an otherwise unobjectionable source of water supply.

216. We may also expect that the state of the Thames and the Lee will be very much improved by the exclusion from them of all sewage and other offensive matter, in accordance with the provisions of the Acts of 1866 and 1868. And it is worthy of consideration whether these provisions should not be extended higher up the tributary streams, so as to exclude all possible sources of noxious pollution.

217. We are of opinion that, when efficient measures are adopted for excluding the sewage and other pollutions from the Thames and the Lee, and their tributaries, and for ensuring perfect filtration, water taken from the present sources will be perfectly wholesome, and of suitable quality for the supply of the metropolis.

218. The analyses made specially for us of the waters in the various parts of the Thames basin are, we conceive, of great interest and value, and will be very useful as data for comparisons of the state of the river at future times. The result shown by them that the present point of intake is the best that could be chosen in the whole course of the river, is peculiarly important and satisfactory.

PART V.

REMARKS ON VARIOUS POINTS BEARING GENERALLY ON THE SUBJECT OF THE METROPOLITAN WATER SUPPLY.

Section I.

ON THE QUANTITY OF WATER LIKELY TO BE HEREAFTER REQUIRED FOR THE SUPPLY OF THE METROPOLIS.

219. The quantity of water that is likely to be hereafter required for the metropolis forms a prominent element in the consideration of any plans of supply, and we propose to devote a few remarks to the elucidation of this subject.

This quantity will obviously depend on two elements—

(*a.*) *The estimated future population, and*
(*b.*) *The quantity to be allowed for each individual.*

(*a.*) As to the estimated future Population to be provided for.

220. The population of London embraced within the limits of the Registrar General's district (see map Appendix AW.), was given for the middle of the year 1867 at 3,082,372 persons.

The number of persons estimated to have been supplied by the companies in that year, as given in the table in Part III. of our Report, amounts to 3,100,000. The districts supplied have a somewhat wider range than that of the Registrar General, as they extend farther into the suburbs; but on the other hand, it is probable that some portions of the population may not be included within the companies' returns.

221. In reasoning upon the probable number of persons to be hereafter provided for, Mr. Bateman states as follows:—

"Will you give us, in the first place, the population of the metropolis in the year 1861?—According to the population returns for that year the population within the district of the Metropolitan Board of Works was 2,803,034 persons. 3–4.

"What is the present population?—The present population, taking the rate of increase at which the metropolis in recent years has been increasing, is upwards of 3,000,000 by estimate. Dr. Letheby, in December 1866, gives the population at 3,067,000 in round numbers. The rate of population has been as follows: it has trebled since the beginning of this century, it has doubled itself in the last 40 years, and it is now half as large again as it was 20 years ago; therefore, at the same rate of increase, in 20 years, it will be half as large again as it is now, and will amount to 4,500,000 persons. I believe that that will scarcely represent the whole population which may be expected to reside in the immediate neighbourhood of London at that time, because the suburbs of London beyond the area included in the district of the Metropolitan Board of Works are so rapidly increasing that they may be taken as forming a part of the metropolis, and ought to be considered with reference to any supply of water."

He gives further explanations of his views on this point, and adds:—

"In 1856 the supply was at the rate of 28 gallons per head per day, in 1866 it was at the rate of 31 gallons per head per day, and in 1867 it was at the rate of 32 gallons per head per day. If you take 32 gallons per head per day as the consumption, and estimate the population in 1877, nine years from the present time, at 3,650,000 persons, which it would amount to at the rate of 1·73 per cent., you will want 117,000,000 gallons a day. If you take the increase at the rate of 2½ per cent., you will want 127,000,000 gallons a day at that time; and if you take it at 3 per cent., which with all deference I think ought to be what you should take it at, you will want in nine years from the present time 132,500,000 gallons a day. Judging from the experience of all the places that I know, I think that is about the right amount to take, and my own belief is that when you get water which can be supplied by gravitation, when you include everybody as you ought to do upon the principle which I have laid down, and compel them to pay for water, and therefore give them an inducement to take it and use more than they have done, when you have converted every privy into a water-closet, and when you have water of the softness of Welsh water, in which case you would sell as much again for trade purposes as you do now, that is an under-calculation instead of an over-calculation, and my belief is that before nine years are over you will want more than 130,000,000 gallons a day. However, I have assumed 130,000,000 gallons, because that happens to be the scale on which I devised these works when I first laid them before the Commission, and that seems to me to be the quantity which may be required about the time at which they could now be executed." 6583–6.

In about 12 or 13 years from the present time he estimates that 170,000,000 gallons will be required, and ultimately 230,000,000 gallons; but he extends his estimates to the provision of 300,000,000. 6632–54.

Mr. Hawksley, on the other hand, does not agree to the probability of the increase continuing at such a rapid rate. He says:

502. "Of course you must add to the present population, and that is a very difficult question, because it is quite impossible to take it that London should increase at the rate it has recently done; we know indeed by the census tables of this kingdom as well as of others that the rate of increase is declining. In all countries the rate of increase attains a certain maximum and after that it declines. Put it as it was in England at the period of the greatest increase; the increase I think was a little over 2 per cent. per annum throughout the kingdom in general. Then it declines and it will go down to $1\frac{3}{4}$ per cent. Then in future periods it will be $1\frac{1}{2}$ per cent., and so on till it comes down to a more moderate rate of increase. In England we have had a wonderful stimulus by the inventions which have been made; the introduction of the steam engine and railways in particular, and the enormous development of our manufacturing power, contributed for a certain period to a most rapid increase of the population, but the increase will not, in my opinion, continue at the same rate; nor is the supposition warranted by the statistical facts gathered in England itself and in other countries as well."

The Government Commissioners, Captain Galton, Mr. Simpson, and Mr. Blackwell, who reported in 1857 on the Metropolitan Main Drainage, considered the question of the probable increase of population for which sewage should be provided, and they estimated the prospective population in the metropolitan districts at 3,578,000 as compared with 2,362,000 in 1851. They also added 401,000 for a suburban area beyond the limits, making a total prospective population of nearly 4,000,000 for which the sewage plan should be laid out.

222. With the view of aiding in the elucidation of this subject, we have had prepared, from the Census Returns, the four diagrams marked Appendices AL, Nos. 1, 2, 3, and 4 respectively.

Diagram AL (1) shows the increase of the population of the metropolis from 1801 to 1861, distinguishing the increase from excess of births over deaths, and that due to immigration. Diagram AL (2) shows the manner in which the increase of the metropolis has been distributed among the persons of different occupations in life. It will be seen that the increase due to immigration is very much the larger, being in the 60 years 1,287,200 as compared with 557,920. It appears somewhat doubtful whether this source of increase will go on as fast as heretofore; it has already diminished from $17\frac{3}{4}$ per cent. in the first 10 years of the period to 8 per cent. in the last 10 years; and if it should decrease further it will prevent the continuance of the increase of the metropolis in its former ratio. The diminished immigration, which probably consisted largely of bread-winning adults, exhibits a check to the increasing means of employment; and this is also borne out by the diminished rate of increase among the industrial classes, which was between 1841 and 1851 nearly 51 per cent., but was little over 11 per cent. between 1851 and 1861. This does not lead us to anticipate an increase in the population of London similar to that of past years.

Diagram AL (3) shows the increase as distributed among the districts of the various water companies, and AL (4) among the various metropolitan districts. This last diagram also gives the population *per square mile* of area in the different districts and parishes. It must be considered, that with the present great accommodation of suburban railways, which will doubtless further extend, the population will be likely to increase principally in the districts lying within a few miles of London, and it will undoubtedly be necessary, as Mr. Bateman suggests, that these districts should be properly provided for as a part of the system of the metropolitan supply. We believe all the companies are alive to this prospect, and have been arranging their plans to meet the wants of these districts as they gradually arise.

223. It is impossible to calculate with any exactness to what extent this increase will go on in any given number of years; but from the whole of the above data we have endeavoured to estimate what increase would be probable, and we are inclined to think that Mr. Bateman's estimate of $4\frac{1}{2}$ millions as the future population to be considered is reasonable, although we should allow more time than he does for this population being attained. In our calculations of quantity, we shall, to be on the safe side, assume an ultimate future population of 5,000,000.

(*b.*) Quantity of Water to be allowed for each Individual.

4038. 224. The quantity of water, per individual, necessary to be supplied in any particular town appears to be very difficult to reduce to any definite rule. It is found that on an average about 10 gallons per head per day are sufficient for ordinary domestic requirements, including waterclosets; but to this have to be added large supplies for street watering, flushing sewers, &c. &c., and for trade purposes and other large

consumption, which in the case of London have been estimated at another 10 gallons. Then in addition to these there is considerable waste, often amounting to, or even exceeding, the whole domestic supply.

225. The following is a resumé of the evidence we have received on this point:—

Mr. Bateman states that the quantity varies very much, according to the character of the place and the class of inhabitants; it varies from 15 to 16 gallons a head a day to 50 gallons. Hence each town and city ought to be taken with reference to its own existing circumstances, and what the probabilities are of the supply being greater or stationary.

He takes the present London supply as equal to about 36 gallons per head per day, and he thinks that this, or even 40 gallons (looking to the constantly growing consumption of water), ought to be the least taken in any estimate of supply for the metropolis. 6–20. App. E.

He states that in Glasgow the consumption is 50 gallons, including, however, a very large waste; and that in Manchester the gross quantity supplied is 21 or 22 gallons per head, of which about one-third is for trade purposes; but as baths and waterclosets are very sparingly used there, this does not afford a safe criterion.

Mr. Duncan states that for a large town, where sufficient care is taken to prevent waste, 30 gallons per head per day would be about the right quantity; but he thinks it will go on increasing in future to probably about 45 gallons, which he would take as the measure of a future supply. 2365–74.

Mr. Hawksley says that in his view 25 gallons would be safe; but if this were extended to 30 gallons he thinks there is no doubt whatever that that would be a superabundant quantity. He considers that 30 gallons per head would be quite a safe calculation for the probable necessity of a population like London—more than enough; including all trades, all waterclosets, stables, incidental causes of consumption, and all household consumption and street watering. 2502. 5088–92.

Mr. Simpson estimates that, looking forward to a few years to come, about 30 gallons per head would be a sufficient provision for the population of London, including all public sewers. 4718–21.

Mr. Hassard states that the Dublin Waterworks are estimated to supply 40 gallons per head, with provisions for a larger quantity if required. He considers that the estimate for London ought to be 50 gallons. 551–62. 865.

Mr. Rawlinson is of opinion that half the water now supplied in London is wasted, *i.e.*, is not used for any useful purpose. Allowing for waste, he conceives 30 gallons a head is sufficient. 1408–11.

Mr. Muir, after much investigation, has found that 10 gallons a day are ample for ordinary domestic purposes, and 20, including all other requirements, for such a city as London. The difference between this and 30 gallons, the present consumption, is due entirely to waste. But he adds,— 4058–64.

"I think a great deal more might be done than is done now for the prevention of waste. The companies, and the New River Company I may say especially, have attempted to check waste to some extent for the sake of the consumers, (for the waste of one set of consumers is very injurious to another, who may be upon a higher level,) and they have succeeded in some measure in reducing waste, without in the least degree stinting the proper supply of their tenants."

Mr. Greaves gives an account of some special investigations on this point which lead him to the belief that the whole population of London ought to be very well satisfied with 24 gallons per head. The results are as follows:— 5143–54.

"Can you give the Commission the result of that?—I can give 15 cases of streets. One street averaged 306 gallons per house per day; the number of inhabitants I do not know; I have taken it per house. Those quantities were determined by the insertion of meters on the supply pipe of the street without any particular information or instruction to the people that they were being metered, but merely as a source of information for ourselves.

"What would you take as the average population of each house?—7½ I should think. No. 1 street comes out at 306 gallons per day; No. 2 at 329 gallons; No. 3 at 283 gallons; No. 4 at 132 gallons; No. 5 at 90 gallons; No. 6 at 96 gallons; No. 7 at 148 gallons; No. 8 at 45 gallons; No. 9 at 87 gallons; No. 10 at 194 gallons; No. 11 at 78 gallons; No. 12 at 358 gallons; No. 13 at 146 gallons; No. 14 at 73 gallons; and No. 15 at 37 gallons."

The average of the whole was 160 gallons per house, or 21 gallons per head.

Mr. Beardmore considers that, including waste, which is enormous, the quantity required for London per head, including trade and public supplies, would not be less than 35 gallons per head per day. 3326–7.

Mr. Dale allows 30 gallons per head for all purposes. The supply at Hull is 32 gallons. 1095–6.

927–30. 943–5. Dr. Letheby considers 20 gallons per head for all purposes a good and sufficient supply. All beyond is wasted.

226. We have endeavoured to collect data as to the supplies in different towns, and Mr. Bateman and Mr. Simpson have communicated to us the particulars given in the tables printed in Appendix AM. It will be seen, however, that the quantities per head for the total supplies vary enormously in the different cases, from 14½ gallons at Norwich to 53 at Glasgow, showing that every case must be judged by its own circumstances.

We conceive, therefore, that the only way to arrive at an estimate for the metropolis which shall have any pretensions to be relied on, is to reason from the present experience, making such alterations as may seem to be necessary for the future.

227. The quantity of water supplied per head in any town may be estimated in two ways; *i.e.*, by dividing the total quantity either among the whole population, or among that portion of them only who take the water, the latter number of inhabitants being frequently much less than the former. In the following table we have endeavoured to give the quantity according to both these methods:—

QUANTITY of WATER supplied to the Metropolis at different dates.

	1829.	1849.	1856.	1867.
Average daily quantity of water supplied - - -	29,000,000	44,383,129	73,376,860	98,600,248
Number of houses and tenements supplied by the companies	177,000	267,305	319,213	441,442
Estimated number of inhabitants therein - - -	1,239,000	1,871,135	2,234,491	3,100,000
(N.B.—Where this item is not given in the returns it is obtained by assuming seven inhabitants to each tenement supplied.)				
Daily supply per head to inhabitants taking water from the companies - - - - - - -	23·3	23·6	33	31·8
Total population of the metropolis - - -	1,572,000	2,280,000	2,583,000	3,082,372
(N.B.—This has been filled in by proportionate interpolation from the decennial census returns.)				
Proportion of whole population supplied with water -	79	82	86	100
Daily supply per head on the whole population - -	18·3	19·4	28·5	32

It will be seen that in 1828 only about 79 per cent. of the inhabitants were supplied by the companies, the remainder procuring their supplies by shallow wells and pumps from the superficial gravel on which London stands. As this source has become worse, by the increasing contamination of the water from underground pollutions, it has been gradually abandoned, and the proportion of persons taking water from the companies has been gradually rising to the present time. It must be remembered, however, that the number of inhabitants in each tenement is merely an estimate, and the districts included extend in some cases beyond the limits of the census returns.

As regards the quantity supplied per head, the table shows that, estimated on the whole population it has increased from about 18 gallons in 1828 to 32 gallons in 1867;—while estimated by the number of persons actually taking water from the companies, it has increased from about 23 to 32 gallons.

228. This is no doubt a considerable increase, but we think it may be accounted for in a way that will not warrant the expectation of its continuance to any considerable extent. During the last 20 or 30 years very great advances have been made in sanitary arrangements; the introduction of waterclosets into houses, the much more frequent use of private baths, and a general advance in domestic cleanliness, have all tended largely to increase the quantity demanded. The companies have met the demand liberally, and all the upper and the middle classes of London may be said to be at present so plentifully supplied with water that further augmentation would be only waste. In regard to the lower classes, there is, no doubt, much sanitary improvement still to be effected, and much more useful application of water still to be promoted; but it is probable

that the improvement will have a tendency rather to check the waste than to increase the supply.

We are not aware that the requirements of trade, or the quantities used for municipal purposes, are likely materially to increase in a larger proportion than the increase of population, so that no variation on this ground need be taken into account.

The only remaining element of change likely to occur would be the introduction of the system of constant service. This would probably not materially affect the quantity of water actually used, but it would have a considerable influence on the quantity supplied, by affecting the amount of waste.

It has been found that where the system could be carried out perfectly, with suitable house arrangements and under efficient control, so far from wasting water it has considerably economized it; but considering the great difficulties that must be encountered in making the change under such disadvantages as will be experienced in London, there is reason to fear that, with every precaution, a considerably increased loss of water will at first be suffered. It is impossible to foretell to what extent this loss may go, or how long it will be before it can be subdued; all will depend on the caution with which the change is made, and the efficiency of the control exercised. But it is to be hoped that before many years after the constant service is commenced, the supply may be brought down again to its normal quantity. And it must be recollected that as the population extends, all new supplies, being adapted (as they ought to be even now) for the new system, will be on the most economical plan. And looking forward further still to the time when long experience shall have been gained of the plan, ample time allowed for making all improvements and changes, and a rigid supervision introduced, it would not be too much to expect that a considerable reduction of the present waste may be effected, and the supply be brought down much nearer than at present to the quantity beneficially used. 2561.

Estimate of Quantity.

229. If these views are correct, we may give the following as an approximate estimate of the quantity to be provided:—

	Gallons per day.
The present supply is, say, for 3,000,000 of population, at 33⅓ gallons per head, equal to	100,000,000
Assume the population to have increased to 4,000,000, and at the same time the additional waste due to the new introduction of the constant service to have increased the supply to 40 gallons per head, equal to	160,000,000
By the time the population has increased to 5,000,000 we may hope that the allowance may be reduced again to 35 gallons, which would give	175,000,000
Or for the maximum summer consumption, say	200,000,000

which we consider the highest demand that need be reasonably looked forward to for the metropolitan supply.

Section II.

PROVISIONS AND PROSPECTS OF THE VARIOUS COMPANIES FOR THE FUTURE.

230. Having thus arrived at an estimate of the future quantity of water which may be required for the metropolis, we have thought it right to inquire what provisions the various companies have made for increasing their supplies as the increasing demands arise. We had previously addressed, to the five companies now drawing water from the Thames, a letter on this subject, which is printed, with the answers to it, in Appendix L.; to these have been added further information given by the engineers of the various companies at our request; and the following statements will, we believe, express the companies' own estimates of their positions and prospective capabilities.

231. The *New River Company* state that from their present sources, and with their existing works, they can obtain the following quantities of water:— App. BF.

	Gallons per diem.
Average flow of the Chadwell Spring - - - - - - -	3,500,000
Quantity which the New River Company are authorized to take at all times from the River Lee, through their gauge at Hertford - - - - -	22,500,000
Additional supply from gathering ground at Cheshunt, &c. - - - - -	500,000
Quantity obtainable from six existing deep chalk wells, upwards of - - -	8,000,000
Water collected in ponds at Hampstead and Highgate, and distributed through separate mains for watering roads and other non-domestic purposes - - -	500,000
Total - - -	35,000,000

In addition to this, there is the produce of a new well now in preparation at Wormley, and also the quantity of unfiltered water that might be drawn from the Thames through separate mains for street watering, &c.

The company are further entitled, by the "River Lee Water Act" of 1855, to increase their supply from that river by storing flood waters, and they believe that under these powers a considerable further addition may be obtained, the New River being capable of conveying twice its present flow. But they have not thought it necessary to mature any plan for this purpose.

The *East London Company* have felt the necessity of largely increasing their powers of supply. They have, like the New River Company, power to store flood water in the River Lee, and in 1867 they obtained an Act to make a considerable increase in their present reservoirs; but they have preferred, as a larger and more certain measure, to go also to the Thames, and they obtained, in the same year, an Act (30 & 31 Vict. c. 148), enabling them to draw from this source a quantity of 10,000,000 gallons per day.

The works authorized under this Act are now in course of construction. The water will be taken from the Thames at Sunbury, about a mile and a half above the intake of the other companies at Hampton, and from this point the water will be lifted to a station at Hanworth, where it will be filtered. It will then be pumped through an iron main, 18 miles long and 36 inches diameter, into a service reservoir on high ground at Hornsey Wood Hill, and thence delivered either into the district for use or to replenish the increased storage in the valley of the Lee.

It is expected the works will be finished in 1871, and that they will cost, under the two Acts, about 450,000*l*. The capabilities of this company may then be estimated at about 30,000,000 gallons per day.

The *Chelsea Company* are empowered to draw from the Thames a quantity of 20,000,000 gallons per day; and they state (Appendix L.) they could pump, filter, and store this quantity without materially adding to their present capital. As, however, their present supply is only half this, we presume so great an increase might overtax the safe and efficient capabilities of the works, unless further mains and pumping and filtering power were provided.

The *West Middlesex Company* have also power to take 20,000,000 of gallons from the Thames. The pumping engines there are already calculated to pump 12,000,000, or more, if worked to their full power; but when this quantity is much exceeded duplicate engines would be required. A new main is already under construction from Hampton to Barnes, which, when finished, will with the present one convey the full quantity. The present reservoirs, filters, and distributing engines are equal to about 15,000,000, but land is provided for the necessary extensions. The mains from Hammersmith to the store reservoirs are of the full capacity.

The *Grand Junction Company* have power to take 20,000,000 of gallons. The present works are calculated to deliver 13,000,000, but are laid out so as easily to admit of extension. A large new covered store reservoir, to hold 10,000,000 of gallons, is now being constructed at Camden Hill.

The *Lambeth Company* are empowered to take 20,000,000 of gallons. They are now duplicating their main from the Thames to Brixton, which, with the former one, will safely deliver this quantity; and the additional pumping, filtering, and reservoir power will be added as required. The works have been laid out, and land provided, with a view to a still larger increase.

The *Southwark and Vauxhall Company* have power to take 20,000,000 of gallons. The works already in operation are capable of supplying about 15,000,000 gallons, but the company are now constructing additional engines at Hampton, with large new reservoirs and filter beds, and are laying down a new line of 30-inch main; and when these works are finished, the whole quantity of 20,000,000 gallons may be delivered when required.

The *Kent Company* state that their present wells will supply 14,000,000 of gallons per day, and that with their present machinery they could raise 10,000,000. One of the wells at Charlton is a duplicate, not yet used. They are now sinking another well and erecting new engines at Deptford, where more water is wanted. 6141.

Summary.

232. It appears from the above data that the various companies represent themselves as being prepared, with their present legal powers, and with only moderate additions to their present engineering means, to supply the following quantities of water:

	Gallons per day.
New River	35,000,000
East London	30,000,000
Chelsea	20,000,000
West Middlesex	20,000,000
Grand Junction	20,000,000
Southwark and Vauxhall	20,000,000
Lambeth	20,000,000
Kent	say 15,000,000
Total	180,000,000

Which is very little short of the quantity we have estimated as the highest demand that need be reasonably looked forward to for the metropolis, but which is still far below the limit of the quantity capable of being furnished from the Thames basin.

Section III.

ON THE SYSTEM OF CONSTANT SERVICE AT HIGH PRESSURE.

233. We have explained in Part III. of our Report that in the distribution of water in London, the water is not constantly laid on to the mains serving the houses, but is only supplied to them during an hour or two each day; this is what is called the "intermittent service" system, in contradistinction to that of "constant service," in which the service pipes are always charged under pressure, and the water may be drawn from them at all times by simply turning the taps in the houses.

234. This constant service system is now adopted in many country towns, and it has obviously many advantages over the other plan. It allows the water to be drawn always fresh from the main, free from the pollution often acquired in dirty receptacles (an evil of great magnitude among the poorer classes), and it ensures supplies at all times independent of cistern storage. It is also a great advantage to have the mains always charged in case of fire, without waiting for the intervention of the turncock, as on the intermittent plan.

Independently, however, of the advantages to the consumers, the constant service plan would seem to be so much more simple and easy to work than the intermittent (which requires much complexity of construction, and trouble of management), that one would think the companies would have adopted it for their own sakes, were there not good reasons to the contrary. In the various discussions that have taken place on the metropolitan water supply, the adoption of the system has been strongly urged; but the proposition has been met by statements of the causes which have led to the adoption of the intermittent plan, and of the difficulties that would arise in attempting to introduce the rival one.

235. In order to make the subject clear we may state at once what these difficulties are; and as far as we can learn, they appear to be five in number.

1. In the first place it is alleged that there is great leakage from the fittings in the houses, producing a waste of water which, though it can be met when it lasts only an hour or two a day, yet if allowed to go on for the whole 24 hours would amount to such an enormous quantity that the supply could not be kept up with the present means or at the present cost. This leakage always takes place to some extent even in the better class of houses, by inattention to the state of ball-cocks, watercloset apparatus, &c.; but it is in the poorer districts, where through carelessness and dishonesty it is impossible to keep the fittings in a respectable condition, that the chief difficulties arise.

2. It is also alleged that assuming all the fittings to be in good order, their strength, particularly that of the lead pipe, though suitable for the small pressure of the intermittent supply, would not be sufficient for the greater strain necessarily induced by constant service at high pressure.

3. The habits of domestic establishments lead the inmates to draw their larger supplies of water at one particular time of the day. During the morning hours the consumption is double the average. Now on the intermittent system this variable draught comes upon the store cisterns, and does not interfere with the power of distributing the quantity pumped uniformly over the day; but under the constant system it would come directly on the mains, and the increased draught at a particular time would lead to much inconvenience. For such of the companies as have no store reservoirs, but are obliged to supply entirely by pumping, the increased draught would require a much greater pumping power to be in readiness, a large portion of it, however, being used only for a short time in the day.

4. This greater draught at a particular time, when it occurred at low levels, would further have the effect of reducing the pressure in the mains and services to such an extent as to render them incapable of supplying at the same time the higher parts of the districts. The leakage also would powerfully contribute to this effect, and thus it would become necessary generally to increase the dimensions of the mains and service pipes throughout the entire metropolis. It is a part of the present system, enforced on the companies by Act of Parliament, to supply the better class of houses up to their highest floors; and as many of these houses are of great height, and stand on elevated ground, a great pressure is required for this purpose. Under the intermittent system this can easily be arranged, but under the constant system these high services would be entirely at the mercy of the draught going on at lower levels. And even in the same building no water could be had on an upper story while lower ones were drawing.

5. In case of any repairs or alterations to the mains, or of any accident whatever interrupting the flow in them (instances of which are said to be of almost daily occurrence in some parts of London), the whole district served by those mains must under the constant system be deprived of water, whereas under the intermittent plan the house cisterns keep up the supply. For this reason it is urged that it is advisable to retain the cisterns, even where constant supply is given, whereby one of the advantages alleged in its favour is done away.

236. Before remarking on the weight to be attached to these objections, we may review what has already been done in the matter, and state the evidence given before us thereon.

Nearly a quarter of a century ago it seems to have been established that on public grounds the system of constant service was the right one, for at the time of the passing of the "Waterworks Clauses Consolidation Act" in 1847 (10 Vict. cap. 17) the following provision was introduced:—

"XXXV. The undertakers shall provide and keep in the pipes to be laid down by them a supply of pure and wholesome water, sufficient for the domestic use of all the inhabitants of the town or district within the limits of the Special Act, who, as herein-after provided, shall be entitled to demand a supply, and shall be willing to pay water rate for the same; and such supply shall be constantly laid on at such a pressure as will make the water reach the top story of the highest houses within the said limits, unless it be provided by the Special Act that the water to be supplied by the undertakers need not be constantly laid on under pressure."

This Act was intended to be incorporated into all Waterworks Bills thenceforth introduced, and it became therefore the law of the land that the constant service system should be applied in all new works, unless special reasons could be shown for its inapplicability.

237. The Board of Health, in their report of 1850, strongly urged that the metropolis should be brought under this system, putting on record the following opinions on the point:—

"That the practice of intermittent distribution occasions, in the case of the better description of houses, the retention of the water in cisterns and butts; and in that of the poorest classes, in tubs, pitchers, and such other vessels as can be obtained; and as a consequence of such retention the water imbibes soot and dirt, and absorbs the polluted air of the town, and of the offensively close, crowded, and unhealthy localities and rooms in which the poor reside."

"That the annual cost of the construction and maintenance in repair of cisterns, and their supports and connected apparatus, in the houses of the middle and wealthier classes, often exceeds the annual water rate."

They also add the following remarks:—

Many practical difficulties have been urged against the substitution of the constant for the intermittent system of water supply in the metropolis, we have particularly examined into the working of the constant system in towns where it is established, and in some of which it has been in operation for 15 and 20 years, and we find—

That the waste of water is so far less, instead of greater, under the system of constant supply, that although the inhabitants have unlimited command of water, and use what they please, though the actual use of water by the inhabitants is greater, the quantity delivered by the companies is less, frequently less by one half, in consequence of there being less waste from the more perfect delivery.

That the water under the system of constant supply is delivered purer and fresher, of a lower temperature in summer, and that it is less subject to frost in winter.

That the inconveniences apprehended from the interruption of supply during repairs and alterations are never experienced, the work being executed under such simple precautions that no complaint has ever been known to have been made on this account.

That the interruptions of supply which are so constantly experienced on the intermittent system from the waste in the lower districts, from the neglect of turncocks, from limitation of quantity, from inadequate or leaky butts and cisterns, or from deranged ball-cocks, are scarcely ever known on the constant system.

That the system of constant supply admits of great economy in pipes, as they may, under that system, for the most part, be considerably smaller, and, not being subject to the violent hydraulic jerks of the intermittent system, are less liable to burst.

That the pipes for the house service may not only be considerably smaller and cheaper, but that the cisterns and apparatus connected therewith, which in the smaller class of houses now cost more than the whole public portion of the works, may be entirely dispensed with.

238. The subject was warmly discussed before the Committees on the Waterworks Bills in the Sessions of 1851 and 1852. The Government wished to carry out the constant service system, but were met by arguments urged by the companies against it, and the result was a sort of compromise, by the introduction into the Act of 1852 of a clause compelling the companies to give a constant service to any district when required by four-fifths of the inhabitants, on its being shown that the pipes and fittings in the houses were in a proper condition to receive such supply. The following is the clause:—

"XV. After the expiration of five years from the passing of this Act, every company shall, subject to the provisions of the Special Act relating to such company, provide and keep, in the district mains already laid down or hereafter to be laid by them, a constant supply of pure and wholesome water sufficient for the domestic use of the inhabitants of all houses supplied by such company, at such pressure as will make the water reach the top story of the highest of such houses, but not exceeding the level prescribed by the Special Act of such company: provided that no company shall be bound to provide a constant supply of water to any district main until four-fifths of the owners or occupiers of the houses on such main shall by writing under their hands have required such company to provide such supply, nor even upon such requisition, in case it can be shown by any company objecting to the same that more than one-fifth of the houses on such main are not supplied with pipes, cocks, cisterns, machinery, and arrangements of all kinds for the reception and distribution of water, constructed according to the regulations prescribed by the Special Act or by this Act, or which any company, with the approval of the Board of Trade, may from time to time make in that behalf; and after any such requisition as aforesaid shall have been delivered to the company, it shall be lawful for the surveyor, or any other person acting under the authority of the company, between the hours of nine of the clock in the forenoon and four of the clock in the afternoon, to enter into any house or houses on such district main, in order to ascertain whether the pipes, cocks, cisterns, and machinery of such house and houses are so constructed as aforesaid; and provided also, that any company may, with the consent of the Board of Trade, suspend the giving of such constant supply, or give the same in succession to the several districts of such company or to any parts of such districts as may be found to be convenient; and provided that it shall be lawful for the company, after due notice, to abstain from supplying, or to cut off the communication pipes, and withdraw the supply of water from any house whereof the pipes, cocks, cisterns, machinery, or arrangements as aforesaid shall not be in conformity with such regulations; provided that neither the Kent Waterworks Company nor the Hampstead Waterworks Company shall be required to give such supply at any height exceeding one hundred and eighty feet above Trinity high-water mark, nor the East London Waterworks Company be required to give such supply at any height exceeding forty feet above the level of the pavement nearest the point at which such supply shall be required."

It would appear that the companies convinced Parliament of the validity of the fifth objection we have given, namely, as to the necessity for the retention of the cisterns under the constant service system, for the following provision was added in clause 22:—

"Whenever water shall be constantly laid on under pressure in any district main, every person supplied with water under pressure by any company through such main shall, when required by the company, provide a proper cistern or other receptacle for the water with which he shall be so supplied."

And then follow provisions as to ball-cocks and fittings, and prevention of waste, &c.

We believe that cisterns are retained to a considerable extent in Manchester and many other towns where constant service is given.

239. The House of Commons Committee of 1867 devoted particular attention to this subject, and as they took a large mass of evidence, embodying the most recent experience on both sides, it may be useful to present at length the conclusions at which they arrived, as set forth in their report:—

67. The Act of 1852 is so framed that the introduction of any constant supply depends upon its provisions relating to the preparation of plans, and the proceedings consequent thereon, but these provisions have been too difficult of application to be carried into effect in a complete or satisfactory manner. With some trifling exceptions, therefore, the metropolis is now supplied by the water being turned on for a short time in each day, except Sundays, when no supply is given to the larger part of the metropolis. The occupiers are left to obtain and store as much of the supply as they may desire, or as the condition of their houses will admit.

68. The use of cisterns for the purpose of storing water for consumption is probably a more fertile cause of impurity than any pollution of the river from which the water is drawn. Decaying animal or vegetable bodies, or other impure matter, may easily find their way into a cistern, and are more likely to engender disease than any impurity existing in the water before it flows into the cistern. In well-regulated houses the cisterns are of course constantly drawn dry, and properly cared for; but as cleanliness decreases, it is found that the cisterns are allowed to become more foul until the lowest state is reached, when the water is stored in tubs and otherwise, under the most disgusting conditions, which cannot but be injurious to health, and a cause of the diseases which are found to prevail in the worst regulated parts of London. On the other hand, an intermittent supply of water without cisterns not only deprives the inhabitants of the supply they ought to receive, but from the want of adequate storage it is kept in pails and other small receptacles, in rooms and places where it is liable to much contamination.

69. For these and other reasons, which will be found in the Evidence, and in the paper of Dr. Farr, No. 7 in the Appendix, and the report of Captain Tyler, which are full of interest, your Committee have come to the conclusion that the Act of 1852 has failed to secure for the inhabitants the advantage which they ought to have long since enjoyed of a well-regulated supply of water in their houses for domestic purposes; your Committee therefore recommend that the Act should be amended by providing that every company should afford a constant supply of water to each house, so that the water may be drawn direct from the company's pipes at all times during the 24 hours, with the exceptions herein-after mentioned.

70. It is right, however, to observe that this recommendation cannot be carried into effect unless adequate provisions are also made to prevent the waste of water which may arise from its being constantly laid on in every house. To determine how far water may be and is in fact now wasted in the metropolis, much evidence has been given which is deserving of notice.

The Committee go on to investigate this matter, and come to the conclusion that out of 78½ millions of gallons supplied daily, about 17 millions are wasted. They then remark:—

75. From experiments made on several occasions in the metropolis, it has been found that where the supply was suddenly changed from the present intermittent system to a constant supply, without any alteration of the arrangements in the houses, there was an enormous waste of water. The experience derived from changes made from an intermittent to a constant supply in other towns, without suitable arrangements within the houses, leads to the same result.

76. Your Committee have therefore endeavoured to ascertain the precise causes of this waste, and the means by which it may be obviated.

77. With regard to the constant direct supply of water to a tap in the house, it appears that no waste is likely to occur if it be so placed and arranged that waste cannot take place without producing inconvenience, which will be immediately felt by the person permitting the waste, and that there are no real difficulties in fulfilling these conditions.

78. All other modes of supply afford opportunities of waste, which it is not so easy to prevent. The ordinary cistern is so liable to occasion waste, that it has been found requisite in other places to lead the waste-pipe into some exposed position, where any flow from it can be immediately detected. It would no doubt be necessary to make this alteration when a cistern is maintained, but as it would be easy to substitute a direct service, without the intervention of a cistern, except for hot-water services or closets, no difficulty need be apprehended on this account.

79. But with regard to the supply of waterclosets, it has been shown that in consequence of the practice of allowing the water to flow through them uninterruptedly for long periods, instead of merely flushing them, they are a frequent cause of great waste, which cannot be detected; there appears, however, to be no difficulty in guarding against this by making such arrangements for flushing, that the water cannot flow on continuously for an unlimited period.

80. It has indeed been objected by some of the witnesses, that it will be found impracticable to maintain any flushing apparatus in proper order in houses frequented by the most negligent people, and that it would be better in these cases to leave them to draw water and flush with a pail. If this were a question affecting the individuals only, such an arrangement might be tolerated, but the health of the public being greatly concerned in the rapid removal of all matters which may either engender the forms of disease, for the most part infectious, found in ill-regulated habitations, or may tend to spread such disorders when they arise from other causes, your Committee are of opinion that the introduction of a flushing apparatus where no water service now exists ought to be imposed on the owner of every house, without prejudice to his right to recover the cost from the tenant, if the latter be under an obligation to incur the expense.

81. The other special services provided with cisterns will be of a limited character, under conditions where the waste is not likely to be considerable, and it will be sufficiently guarded against by the arrangements recommended.

82. It has also been objected by some of the witnesses that there is no remedy for one of the chief causes of waste in certain localities, which is to be found in the tendency of evil-disposed persons to take away all fittings of brass or copper.

83. Your Committee have, however, been informed that it is not impossible to remove much of this temptation by reducing the present use of copper and brass in such fittings; but as the removal of the fittings undoubtedly causes great waste of water and loss to the companies, as well as great inconvenience and injury to the public, your Committee are of opinion that the unlawful removal of fittings should be made a specific offence, punishable summarily with imprisonment, and that the sale of such fittings, if marked with some certain initial letters, should be placed under the same restrictions as the sale of stores with the mark of the Crown on them, by which the unlawful traffic in such fittings would be repressed.

84. It has been further objected, that if the constant supply were laid on in each house, there would be great danger of the house pipes bursting in frosty weather; but it has been stated in reply, that this cause of danger may be easily obviated by the water being turned off at the stop-cock at night, and the house pipes being emptied by drawing the water off at the lowest tap in the house. This precaution is so simple as to render the objection undeserving of further consideration.

85. It has been urged by the water companies that a constant supply would endanger the pipes which have been laid down by the owners of houses between the house and the pipes of the company, called communication pipes; but as this would depend upon the arrangements which the company might think fit to make to regulate the pressure or height of the head of water supplied, which would involve much interference with the operations of the company, your Committee recommend that all the communication pipes under the

streets and pavements, up to and inclusive of the stop-cock, if any therein, should be vested in the company, and that all future communication pipes up to and including a stop-cock, should be laid down by the company at established rates of charge, at the expense of the owner, and then vested in the company, and that both those now and hereafter laid down should in future be kept in repair by the company; that it should be penal to use the stop-cock contrary to any rule of the company for cutting off the supply of water.

86. The companies would thus be left free to make their own arrangements so long as they deliver a sufficient supply of water for the upper storey of each house within the limits of height which are or may be prescribed.

87. It may be necessary to make an exception to meet the case of rows of houses of small value. It has been suggested by some of the witnesses that, for the sake of economy, these houses may be supplied by a small iron pipe, running through the houses, with a separate branch pipe and tap for each house. Your Committee recommend that in this case the companies should not be required to provide more than one communication pipe, with a stop-cock at the commencement of the through iron pipe; but it being impossible to define beforehand the occasions when this arrangement may be desirable, it should be left to the inspector to decide in each case in the event of disagreement between the owners or occupiers and the company.

88. Considering the improvements that are constantly taking place, both in economy and perfectness of construction in mechanical contrivances, and the difficulty of providing against inconvenience which may arise, your Committee do not think it desirable that any precise mode of effecting a constant house supply, or any particular kind of apparatus, should be enjoined in a statute, but that the companies should be required, in conjunction with the Metropolitan Board of Works, to frame rules, with power to alter them in like manner, for the purpose of prescribing the arrangements within the house to carry out the general principles above noticed, and that any violation of these rules should be penal.

89. To facilitate the application of these rules at the least possible expense and inconvenience to the owners and occupiers of houses, your Committee recommend that the companies should at the request of the owner or occupier provide all the fittings and apparatus required by their rules, and keep them in repair at established rates of charge, in estimating which due regard should be had to the fact that they would have to make a periodical inspection for their own protection at their own expense; and that when the fittings and apparatus are supplied by others, they should be put up in the prescribed manner, to the satisfaction of the water company, and that for this purpose standard patterns should be kept by the companies and by every local authority in the metropolis.

90. The constant supply of water to each house thus recommended will no doubt entail upon the companies a watchful supervision on the internal fittings and apparatus, for which sufficient powers are contained in the Acts above noticed; but as they will be relieved of the trouble and expense of turning on the water, which they now have to do under the intermittent system, your Committee do not consider that the companies have any valid objection or claim to indemnity on this account.

240. We may now give a summary of the evidence we have ourselves received on this point.

Mr. Hawksley says that the question of having a constant high level supply in London

Is a question of the magnitude of the pipes, and that only. The fact, as regards the piping and the constant supply, is this, that at certain periods of the day, generally between 9 o'clock and 11 in the morning, the quantity of water that is delivered is double the average quantity for the whole twenty-four hours, and consequently the main pipes must be made large enough for that purpose. Where the supply is given on the intermittent system the companies spread the delivery just as they think fit over a great number of hours, as much in one hour as in another, but on the system of constant supply they lose the command of the delivery entirely. 2257–63

2558. What is your opinion with regard to the constant supply as compared with the intermittent system which is now in operation?—The constant supply is much more beneficial than the intermittent supply *per se*, the difficulty is in changing from the one to the other.

2559. Is that difficulty in the mechanical arrangement in the pipes and taps, and so on?—Chiefly so. Of course you must have a different organization from what you have now—in point of fact there is scarcely any organization—and people must submit to the inspection of their premises from time to time, but that need not be unpleasant nor need it be frequent.

2560. Under proper inspection, assuming always that the pipes are equal to the pressure and the taps properly formed for the constant supply, do you think that the health of the public would be promoted by having their supply of water constant instead of holding it in vessels that are unsuited to the purpose?—As regards the poor I have no doubt that it would be so, as regards the middle and upper classes I do not think there is anything in that point, because we all have in our own houses admirable receptacles for water; it is quite immaterial to us.

2561. Even under proper regulations is it not your opinion that there would be a waste of water with the constant as compared with the intermittent system?—No; that I can give the fullest answer to. On the contrary, where the constant supply is well managed the waste of water is less than upon the intermittent system. I can give you a very remarkable instance, one among a considerable number, but it is so remarkable in itself that it is worth mentioning to you. A few years ago the City of Norwich Waterworks were transferred from a very old-fashioned company to a new one, by whom the system of constant supply had been accepted under an Act of Parliament, that is to say, it was imposed upon them. They tried to work it upon the old principle, and the consequence was that in a very short time the delivery amounted to 40 gallons per head per diem, and that amount of consumption exhausted all their pumping power. They could do no more, and the consequence was that they were obliged to shut off the water at night, and the company fell into a state of ruin; all their efforts were insufficient to check the waste, and the work was very nearly being closed. I was called in amongst other persons, and they obtained a very good manager, and under my advice they applied for an additional Act of Parliament to enable them to correct the fittings. With some difficulty—for the bill was opposed, as is almost always the case, for there is great jealousy about internal inspection, and so on—the bill was carried and it was put into operation, and now and for many years past, although the constant supply has been unfailingly in use, the water is never shut off, and the consumption has descended to 15 gallons per head per diem as compared with 40 previously.

5100–5. Mr. Hawksley agrees that the poor ought to have an abundant and constant supply of water, but they ought to be prevented, by proper means, from wasting it. He says,—

A constant supply, with proper regulation and proper supervision, takes less water than an uncontrolled intermittent supply; but then you must have that regulation and supervision, and if the public will not submit to the expense and will not submit to the inspection, nothing can be done for them; but if the Legislature choose to empower the companies to make it compulsory upon the landlords, through some other authority, to put everything in a proper state of repair, and keep things in that proper state of repair, there is no reason at all why the constant supply should not be granted to-morrow. I do not think that there is any company in London that would think of resisting it; but they are all in a state of alarm now, because they know perfectly well that if they were to turn on the constant supply to-morrow, probably three-fourths of the houses in London would receive no water. I should not get any water myself, it would all be draughted off into the lower districts, and run away in waste. But that is not so in the towns where there is a constant supply, and where those powers are conceded and where they are properly acted upon.

2621–2. Mr. Simpson says the constant service would be a very difficult thing to apply, unless the companies have more power; in fact it must become a question of police, or he does not see how it can be applied. He adds,—

There is an immense difficulty in dealing with the supply of the poorer neighbourhoods, and one which I confess they have never been able to surmount. Some years ago I took great pains on behalf of the Chelsea Company, who were taunted with the want of supply to the inhabitants of Westminster, to lay down pipes from the mains and have water constantly on. Immediately that was done the middle men sold all the cisterns and leaden pipes, and in the next year they refused to pay the money. They said that their tenants had not the water and that they had a right to the water, and in the course of seven years the whole of that work was destroyed which cost the company 800*l*.

We have the greatest difficulty with those small properties. It is nobody's interest to preserve the fittings, at least nobody does interfere. It is a part of the pastime of the children to injure them, and the least thing that would fetch a penny they will steal. The stealing of anything in the nature of metal goes on constantly.

4699. There are such difficulties attending it, and I hear of them on all hands, that I think it is not only a large experiment to introduce, but it would require an amount of interference almost greater, I think, than we should carry out in the metropolis.

4699. 4717. He gives a long statement to show the great difficulties which have been found at New York and in Boston, through the waste of water; and further discusses the subject as will be seen in the evidence.

4055. 4065–76. Mr. Muir, being asked whether he sees any practical difficulties in the way of constant supply, says,—

In London there are no doubt great difficulties. In a town to be supplied for the first time I think everyone would admit the desirability of a constant supply, care being taken to have everything in reference to the fittings of the houses of a proper description, and means being taken to have such supervision as would keep everything in order. The difficulty in London will arise from the amount of change required to make *old* premises ready to receive the constant supply. The position of the New River Company has always been this, that if their consumers will only take the supply without waste there would be no objection to give it on the constant system, and the advantages of the constant system would be very great in the houses of the poor. I think that the one disadvantage of the intermittent system is its needing cisterns that are liable to become fouled; and in the houses of the poor it is a most difficult matter to have cisternage so placed as not to acquire some foulness by vitiated air or other contamination. The New River Company have repeatedly offered to furnish the houses of the poor with a constant supply if the landlords of such property would only take water in some way that would insure the company against waste.

Were a constant supply introduced it would be necessary to have very strict supervision indeed, for the purpose of preventing waste, and if that strict supervision could be borne by the inhabitants, and if the requisite power were granted to the companies or to local authorities to control the condition of things in houses, I think that the supply might be brought within more reasonable limits than it reaches to now.

You have been examined upon that point before Mr. Ayrton's committee, have you not?—I have.

Do you advocate the entire abolition of cisterns in the case of a constant supply?—Not at all. I think it would be a very inadvisable thing. I believe the whole question was gone into in the years 1851 and 1852 before Parliament, and the result come to then was that cisterns should in all cases be provided, and it is so arranged in the Metropolis Water Act of 1852. I think in all houses of a better description, where there is a possibility of putting cisterns in proper places, cisterns should still be required, and only in the houses of the very poor should cisterns be dispensed with, and water taken on the constant system through some waste-preventing apparatus.

Although you would retain the cisterns, you would still have a constant pressure upon your mains?—There would still be a constant pressure upon the mains, and a constant pressure upon all mains would be decidedly an advantage, especially for fire purposes. When I speak of mains under a constant system I mean all the companies' pipes, because at present a portion only of the companies' pipes are always charged, and they alone are called "mains" by the companies. Other portions (the branch pipes of the companies) are intermittently charged, and they are called "services." The effect of giving a constant supply to all those pipes would be to enable a direct fire supply by a hydrant to be taken from the "services" as well as from the "mains." But I still say that the difficulty arising out of the enormous expense which would be thrown upon the owners of house property in making houses fit to receive a constant supply would be so great in London, that a general adoption of the constant system here appears to be almost impracticable.

Of what could that expense chiefly consist?—It would chiefly consist in laying down new lead pipes for those at present in use. Many of the lead pipes in London are very old and very feeble, and the least increase of pressure would cause them to give way. The fittings are also of a very imperfect kind. Under the intermittent system those pipes are all saved from the night pressure. The pressure of water at night, when no one is drawing from the mains, is very much greater than the pressure during the day, and as houses are now served, those lead pipes are only subjected to pressure during the day and are saved therefore from the higher

pressure of the night. Under the constant system they would come under that higher pressure, and in the great majority of cases they would give way.

If your view is correct that you could reduce the consumption per head from 30 gallons to 20, there would be a saving in that case of water to the water companies of 33 per cent. ?—There would.

Would not that saving of 33 per cent. in the quantity of water that they supply enable the water companies to bear such an expense as would be involved in the alteration of the services to the houses ?—I think not.

Would the system of constant supply entail a large expense upon the water companies ?—To a certain extent. The New River Company has already incurred a very large expenditure in preparations for the constant supply. It was arranged by the Metropolis Water Act of 1852, that the companies should prepare themselves after an interval to give a constant supply, and that if four-fifths of the inhabitants on any district main should come to a company asking for a constant supply, and put themselves in order to receive it, the company should be bound to give it. Under those Acts of 1852, 1854, and 1857, which I mentioned, the New River Company laid out something like 800,000*l.* in the general improvement of their supply, providing filtering beds, laying down large new leading mains, and constructing high service covered reservoirs, all of which were in preparation for this improved constant supply. As yet no applications have been made for a constant supply, and a constant supply therefore has not as a general rule been given, though there are exceptional cases in the New River district where the supply is constantly on.

What do you understand by the householder putting himself in a position to receive the constant supply ?—The lead pipes must be made of sufficient strength by him, that is, for his own sake. He must take the water for the watercloset use out of a service cistern with a double valve, so that there shall not be waste in the watercloset (one valve always being shut while the other is open). While the water is being drawn into the closet the water is prevented from coming from the main into the cistern, and so waste is effectually prevented. He would require to have all his ball-cocks and taps of the best description, and one thing which has been found almost always necessary in every house in which a constant supply has been given is to forbid overflow of waste-pipes from cisterns, so that consumers shall have a very good reason for taking care that ball-cocks are always in perfect working order.

What do you calculate the average to be per house for making those necessary alterations ?—I have calculated that on the average, to do the thing properly, it would take something like 8*l.* per house all over London in order to put the houses in proper condition for receiving the constant supply.

That 8*l.* would lie between two extremes; what would it be for a small house, and what for a large one ?—I think for a small house it might take 4*l.* or 5*l.*, and in larger houses a very great deal more.

Would you say 12*l.* or 14*l.* ?—Yes. Where the pipes are built into the walls and have to be cut out and the decorations made good, the expense might be 20*l.* and upwards. In some cases it has been said and often felt, I believe, that the companies obstinately stand in the way of a constant supply. I do not think that at all to be the fact. If a constant supply could only be carried out here in London as it is said to have been carried out in some other places, with a great reduction in the quantity of water consumed, the companies should hail it; it would be a great matter to them to be able to dispense with the services of many turncocks, and save water at the same time.

Mr. Greaves says:—

I myself am rather an advocate for a constant supply on the whole. Of course claiming to have the privilege of putting a reduced orifice somewhere on the pipe so as to prevent inordinate waste, I find no difficulty in giving a constant supply in my district. I have now 25,000 houses out of 92,000 who are continuously from year's end to year's end on the constant supply system. 5156–66

Will you explain what you mean by a reduced orifice ?—Somewhere in the pipe between the pipe which belongs to the company and the cistern which belongs to the consumer, a disc with a small hole in it is inserted so as to prevent the water being drawn beyond a certain speed. That limits the draught of the system, and it saves us from inordinate loss which we know we should suffer, because notwithstanding that we have 25,000 tenants supplied in this way we cannot leave them unguarded, we are obliged to visit and inspect continuously over and over again.

That limits the size of the supply pipe to the cistern ?—Yes.

What class of houses do you supply in this way ?—We supply without distinction now.

But does that include any of the poorer class of houses ?—Yes; in fact seven-eighths, perhaps nine-tenths, of all the houses that we are laying on now we are laying on upon the constant system.

And all upon that principle ?—Yes, all upon that principle.

With regard to the poor people your experience would be, I presume, that it is of vital consequence to them to have a good supply of water ?—Yes, it is. I advocate giving a complete and good supply to the poor on every possible ground, moral, social, and physical, with reference to the ordinary comforts of life. I think the absence of a proper supply of water to the poor is one of the grievances of the day.

When you do adopt that system and apply a contracted disc for the water to pass through you have of course to assume that you will allow them to have a certain supply in 24 hours ?—Yes, certainly.

What do you assume in that case ?—I assume, say 180 gallons in 24 hours per house, that is the maximum, that is to say, if they have no ball-cock nor any check upon it and they were to rob me to the utmost they could only take to the extent of 180 gallons a day. A pint a minute is 180 gallons a day.

Have you found that the constant supply to the poorer class of houses has led to any greater waste of water than under the intermittent supply ?—I do not think it has.

He also describes some contrivances introduced by him to prevent waste. 5202–5.

Mr. Beardmore considers that under any system cisterns must be used. He says:— 3347 *et s*

I do not see any possibility of dealing with the general humanity, as you may say, without them. If you have such waste as you have in the low districts in London no pipes can furnish water constantly and with high pressure. You cannot deal with it. If you have a fraudulent or a careless man in one house he is wasting water away, and of course he is diminishing the head to the person next door, that is the difficulty you have got—to protect everybody and to give an equal pressure. At this moment I have the general advising and management of a small board of health town near London, and we profess to give a constant service, but it is perpetually breaking down; one wrongdoer opens a cock, and there is the whole thing at an end, and we have perpetual difficulties, and now I am dividing the services. At Enfield, I have reduced the pressure from 170 feet for the low district to about 35, and the landlords of the houses have already thanked us for doing it. The expense of keeping up the fittings was so great that they liked the low pressure better.

He instances the rigid supervision necessary in towns where constant supply is given, and thinks it would be impracticable in London.

Being asked whether the health of the inhabitants would be promoted by the constant supply system, he says:—

I cannot say that, because I think the real evil is the iniquitous state of the poorer class of houses. They have no sort of cistern at all, and if you made it absolutely requisite to have a very moderate amount of cistern, and proper arrangements for taking in the water, and could keep the people from stealing the apparatus, you will be as well supplied by the present system as by the constant system. At present, in the low parts of London, in the east of London, you cannot keep a tap on a pipe at all; everything goes.

He adds further remarks on the subject.

5587–686. Mr. McClean has adopted the constant service system extensively in waterworks in Staffordshire, and believes it is the proper system. He has found no difficulties in applying it.

3813–18. Dr. Letheby says:—

As an abstract question, there can be no doubt that the constant supply is a very advantageous thing to the public, chiefly because they would get their water cooler, more grateful, less liable to the pollution to which it is now subject after it is delivered by the water companies, and, if the question really turned upon poor people's houses, I should say that the constant supply to them, whether it be in a court by a standpipe, or whether it be in their own yards by a standpipe, would be a boon, the good of which is hardly to be calculated.

2720–25. Dr. Lyon Playfair expresses his opinion of the advantage of constant supply, which he says

Delivers the water always cool and in good condition; it obviates the necessity for a number of cisterns in badly ventilated houses, and especially in the houses of the working classes, and so prevents a great source of the danger of epidemics which arise from the solution of the polluted atmosphere in the water.

3162–8. Dr. Parkes prefers the system of constant supply as doing away with the evils of house storage. He says,—

"There are great sanitary advantages in a constant supply, namely, in doing away entirely with the house storage. The house storage entails a great chance of the water being impure, either from the cisterns being allowed to get filthy or from substances finding their way in from the overflow pipes communicating with sewers and drains, and gases forcing their way back through imperfect traps. All these evils the constant supply entirely does away with, but the disadvantages of the constant supply are certainly the very great quantity of water that is wasted, and the occasional failure at times when it is very important indeed to have a large supply of water. For example, last year, in Southampton, in the time of the cholera, when it was extremely important to have the drains well flushed, and everything carried out, we had rather a failure in the supply of water in the low parts of the town. The population in the higher part of the town being nearer the reservoir used a very large quantity of water owing to the dryness of the season, also their gardens required a large quantity of water, and this was taken from their constant supply. At the same time there happened to be also some alterations going on in the pipes and in the machinery, which also lessened the quantity. The consequence was that we were unable in the low parts of the town for several days during the prevalence of the cholera to ensure a proper quantity of water passing through to the sewers."

"Assuming that you have an ample supply for the whole population of a town, are you of opinion that the system of constant supply for all sanitary purposes is infinitely superior to that of an intermittent supply?—Quite so, if you can get over the practical difficulties and the enormous waste, but I think that if you have the constant supply it must be understood that there is to be no stint in the water in any part of the district at any time as there appears to be in some towns which are supplied with the constant service."

2771 *et seq.* Dr. Simon considers the system of intermittent supply to be a very bad one, for reasons he gives at considerable length.

"Do you consider the system of intermittent water supply to be a good or bad one?—A very bad one.

"What is the reason which induces you to consider it a bad one?—My opinions about it are substantially those which I expressed in 1849 and 1850, in the following passages of my reports then made. From report of 1849:—'I consider the system of intermittent water supply to be radically bad, not only because it is a system of stint in what ought to be lavishly bestowed, but also because of the necessity which it creates that large and extensive receptacles should be provided, and because of the liability to contamination incurred by water which has to be retained often during a considerable period. In inspecting the courts and alleys of the city, one constantly sees butts for the reception of water, either public or in open yards of the houses, or sometimes in their cellars, and these butts, dirty, mouldering, and coverless, receiving soot and all other impurities from the air, absorbing stench from the adjacent cesspool, inviting filth from insects, vermin, sparrows, cats, and children, their contents often augmented through a rainwater pipe by the washings of the roof, and every hour becoming fustier and more offensive. Nothing can be less like what water should be than the fluid obtained under such circumstances, and one hardly knows whether this arrangement can be considered preferable to the precarious chance of scuffling or dawdling at a standcock. It may be doubted, too, whether even in a far better class of houses the tenants' water supply can be pronounced good. The cisternage is better, and all arrangements connected with it are generally such as to protect it from the grosser impurities which defile the waterbutts of the poor, but the long retention of water in leaden cisterns impairs its fitness for drinking and the quantity which any modern cistern will contain is very generally insufficient for the legitimate requirements of the house during the intervals of supply. Everyone who is personally familiar with the working of this system of intermittent supply can testify to its inconvenience, and though its evils press with immeasurably greater severity on the poor than on the rich, yet the latter are by no means without experience on the subject.'"

He goes on to explain the large waste which takes place on the intermittent system, and which, he conceives, reduces the average available supply for domestic purposes within the city to only a quarter of its alleged quantity.

Mr. Holmes, the borough surveyor of Sheffield, says he does not see any advantage in substituting the constant for the intermittent supply except in case of fire; there must be a great waste in the former, going on by night as well as by day. He adds, however, that with pipes capable of withstanding the pressure, he would prefer a constant supply. 4884.

Mr. Dale is arranging a constant supply to Hull. He has found no inconvenience; on the contrary, the leakage is less when the constant supply is given. The inhabitants prefer the constant supply. He says in reply to the question— 1107-19.

"Have you experienced any inconvenience arising from the constant supply?—None at all; far from it; there is far less leakage I should say, and I have tested it in fact. I should say that on the eastern portion of the town there is a saving of 25 per cent., or say 20 per cent. to be on the safe side, in the leakage, compared to what there is on the other side of the town."

He explains how he tested the quantities supplied to each side of the town, and further adds—

"Have you had any complaint from the inhabitants with regard to the change of system?—The inhabitants are continually crying out for a constant supply, they prefer it to intermittent."

Mr. Quick gives evidence as follows in regard to constant service:—

"I think that in the poorer districts it might be an advantage, but I think that practically the better class houses have the best constant supply that they can have by having a good cistern in their houses, by means of which, in the event of any interruption from the breaking of a main, or a conflagration in the neighbourhood, or anything of that kind, they have a supply of water which will last them two or three days in there own cisterns; whereas if they merely depended upon a pipe passing into the house, the moment that there was any interruption to the flow in the main they would be deprived of that accommodation. 6014–92.

Then are we to infer that you are not in favour of the constant supply system?—I think that it has its evils. Perhaps in a poorer neighbourhood it might be an advantage, but I think where cisterns are properly taken care of and cleansed, and so on, that is the best constant supply that anyone can have. In fact, I do not know how the constant supply system is to be arranged in a house, where the kitchen boilers, for instance, require constant filling; and with regard to waterclosets, again, it would be an exceedingly inconvenient thing to have water absent from the house probably for 24 hours in the case of an accident to a main, or anything of that kind.

Are the accidents to the mains of which you speak frequent?—The large valves want repairing occasionally, and the mains will break now and then, and alterations are necessary, such as putting on new branches to a main, and when the main has to be cut out and a connexion made to it to go down a side street during the whole of that time, which may occupy several hours, if there were no storage the people would be deprived of water.

Mr. Quick gives a statement of 4,300 different works done in the Southwark and Vauxhall Company's district during the year 1866, in each of which cases it was found necessary to keep the stopcock on the main or service pipe shut for periods varying from one to twenty-four hours.

Being asked whether the expense of keeping the pipes and fittings in repair would prevent the system being carried out, he says—

We find great difficulty in getting the owners of small property to lay out a single sixpence for benefiting their tenants in any way, and I am quite sure that any representation that the companies could make would never induce them to do it unless there were some legislative power to compel them.

Has your attention been directed to the principle of a constant supply in regard to its effect upon the public health?—I think, as I have stated before, that in the poorer districts there would be a great advantage from the constant supply, but in the better class of property I cannot conceive that there would be any advantage at all in respect of health.

A constant supply would have its advantages for the purposes of fire, would it not?—I think there is a great question whether it would or not.

I mean under proper pressure?—That is the difficulty. If there are so many thousands of taps in connexion with the mains, there will be always a certain amount of draught passing into the district which will lower the pressure. At the present time the whole of the trunk mains or principal mains of the district are kept under the full pressure all night, and in case of fire they have only to open one of the side cocks and direct the water to the particular place where the fire may be burning, and all the pressure can be directed by merely opening these one or two cocks, whichever it may be.

But I wish you to direct your attention not to such a pressure as that the fires might be extinguished from the hydrants by application of the hose, but to such a pressure as would keep the pipes charged and the supply sufficiently full to be pumped by means of a separate fire engine.—That can always done by the mere opening of one of the side cocks leading from the trunk main.

The difficulty now is to find water, is it not, in case of a fire?—The water is always in the main.

A recent case occurred where water was not to be obtained in any quantity for useful purposes for more than 20 minutes after the fire, and the destruction was pretty well completed, how do you account for that?—I think that that arises principally from a want of understanding between the brigade and the water companies.

Being asked what it would cost to put the fittings into proper order to receive the constant supply, as required by the Act of 1852, he says:

It depends upon the class of house, in some cases it might cost 2*l.* or 3*l.*, and in others 10*l.* or 15*l.* per house.

In the present system of supply is it not one of the great objections to the cistern system that those cisterns are not kept clean by the owners of the houses themselves?—That is so.

And if they got the water direct from the pipes, they would get it, would they not, in a purer condition?—There is no doubt of that.

Your view perhaps would be that it would be a necessary thing to have a combination of cisterns and a supply direct from the pipes in the same house?—Yes.

Up to the present time the practical effect of the clauses in that Act of Parliament has been, has it not, that no company has been called upon by the inhabitants to give them a constant supply?—That is so.

Do you think that the water companies themselves would object to it if they were called upon by the inhabitants, and if the inhabitants were to do their part of the duty?—I do not think they would. Of course the water companies would have to lay out a very large sum of money to enable them to do it, and I had perhaps better explain why that would be so. It is on account of the undulations in the districts. In the Grand Junction district there is some portion of it but little above the level of the Thames, whereas other portions are nearly 200 feet above the level of the Thames, and it is constantly rising and falling; and of course if the water is allowed to run to waste in any way in the lower portions of the district, unless there is a division of the trunk mains the high portions would never get any water at all.

Still there would not be an objection on the part of the companies to that outlay?—I think not, if proper provisions were made.

And it would necessarily be attended with much greater stringency of supervision on the part of the water companies?—Yes.

Do not you think that the result would be great economy in the consumption of water per head?—There might be an economy in the quantity of water pumped, but the difference of cost to the companies would not be any very great deal. You would not reduce the expense of management, or labour, or anything of that kind; it would be the mere expense of pumping.

Still there would be economy in the actual consumption per head?—Yes; there is no doubt there would be less water used, supposing that all the fittings were put in a proper state to prevent waste.

Mr. Morris's evidence is as follows:—

6155–60. But you think that a constant supply would be a very good thing?—I do, if we could once prevent waste, or if we had power given to us to prevent it, or any mode were devised by which we could get rid of the enormous waste which is attendant upon a constant supply as carried out under the present system, we have no objection.

When you say if you could get power given you to do so, have you ever considered what powers would be satisfactory for preventing waste?—I think that the power which would be required must be vested in what we may call a water police; there should be a constant inspection, which I know that the public would not bear, but unless we had power to exert that, it is perfectly out of the question. I have made some experiments, and I know that people have wasted as much as 2,000 gallons a day per house for a twelvemonth together.

Having regard to a properly arranged system of supply, pipes of sufficient strength to resist the pressure, and an efficient supervision, you are of opinion in the first place that a constant supply would produce a great saving of water, and in the second place promote the health of the inhabitants?—I will confine myself to the saving of water. I have no doubt there would be a great saving of water, but the restrictions must be very stringent, otherwise it would completely absorb the whole of our power of supplying; you might pour water upon the sea beach with as little effect.

You think it necessary, if I understand you aright, to have some very stringent police regulations?—I do not say police, but something of that nature, persons armed with authority who could go into the houses and prevent waste.

6269. Dr. Frankland says:—

"With regard to the deterioration of the water by storage in cisterns and in tanks, I think that too strong an opinion can scarcely be expressed. In my own house, when I first went to it, I found that the waste pipe from the cistern which was to supply us with water was not furnished with a trap at all, but that there was free communication between the sewer and the interior of my house through this pipe, and sewer gases were brought just upon the surface of the water in the cistern, and I believe that is the condition of most of the houses around me at Haverstock Hill."

6589–6604. Mr. Bateman has given us a paper he wrote on this subject a short time ago, and which, as it is well worthy of attention, we have reprinted in Appendix I. He advocates the constant service system, but it will be seen that he is by no means insensible to the great difficulties that would be met with in making the change in London. He adds, in his evidence, remarks as follows:—

"I may state that my own opinion is that a constant water supply under high pressure in the existing state of the plumbing in London would be almost impossible, and that it is necessary that very stringent powers be given to the companies or to a corporation, if it had the administration of the water, to compel all the parties to put their water fittings into perfect order before the constant supply was given. Even the Welsh district would be almost insufficient to supply London under the constant system, as the fittings are now; but if proper care be taken that the fittings be all properly put in order, and a very strict supervision exercised, I find as a matter of experience that towns supplied under the constant system do not take more water than those which are supplied under the intermittent system. The consumption of water in Glasgow is 50 gallons per head per diem, where water fittings are as bad as they can be, as bad as they are in London (and that is about saying the worst thing for them), and the waste is very great indeed; I forewarned them against this, and for a time very active supervision reduced the waste after the introduction of the Loch Katrine water; but they consider that they have an inexhaustible supply and that it tends to sweeten the Clyde and flush out the sewers, and they allow the waste to go on, but all that might be corrected."

He further adds particulars as to the advantage of constant supply in cases of fire, as illustrated in Manchester. He says:—

'The per-centage of property destroyed from 1846 to 1850, before the introduction of the water, was 21·3 per cent. of the value of property attacked by fire. The amount saved out of such property was 78·6 per cent. From 1851 to 1855, Manchester, for half the time at least, not having advantage of high pressure, and for the latter two years of the time having it, and therefore it would be partly under the old system and partly under the new, the per-centage of property destroyed was 12·9 per cent., and of that saved 87 per cent. Then came the advantage of the constant supply and high pressure, with a full water supply, and from 1856 to 1860 the per-centage destroyed was only 7·7 per cent., being only one-third the amount which was destroyed

before the introduction of the fresh water supply, and the amount saved was 92·2 per cent. From 1861 to 1865 the amount of property destroyed was 6·7 per cent., and the amount saved was 93·2 per cent."

He believes that the expense of alterations in the houses, to receive the constant service, has been much overrated as regards the better class of dwellings.

Mr. Rendle, a medical gentleman who has been very active in promoting sanitary improvements in Southwark, gives examples of the defects in the London supply, for which he believes constant service is the only remedy. 6749 *et seq.*

Mr. Heron, town clerk of Manchester, states that no difficulties of importance have been found in introducing the constant service into that city, and that in the small houses cisterns are dispensed with. There are, however, no waterclosets in the small houses. The arrangements for extinguishing fires are very complete and efficient. Cisterns are useful in cases of stoppage of the supply in the main, though such accidents seldom occur. 7330–41. 7349–53. 7367–70.

His impression is in favour of the economy of the constant supply, but the regulations to prevent waste must be very stringent. He says:— 7386–90.

"We have most ample powers with reference to fittings, and also for the purpose of inspection.

"7388. Would not a similar power be a matter of absolute necessity in the case of London being put upon the constant supply system?—I should think it absolutely necessary in any case. I think it is quite right that whoever is supplying water, whether it is a corporation or a company, should have ample power to see that the water is not being improperly wasted.

"7389. Do you find any complaints from owners of property of such supervision being at all inquisitorial?—Not at all; I never heard a complaint of the kind, and we have found it to be most necessary."

He gives, in answer to question 7390, a list of the regulations provided by Acts of Parliament for this purpose.

Remarks by the Commission.

241. We are of opinion that the mode of distribution is a most important point, particularly as bearing on the health and comfort of the poorer classes; and we agree with the conclusions arrived at on previous public inquiries, that earnest and prompt efforts ought to be made to introduce the constant service system to the farthest extent possible, in the supply of the metropolis.

242. The provisions of the Act of 1852 in this respect appear to have been ineffectual, and we are not unimpressed with the difficulties of the case, which we fear would be beyond the power of being successfully dealt with by the present companies. The legal powers they now possess would not be sufficient to enable them to control the house arrangements, or to check the enormous waste that would arise on the introduction of the new system. And we do not see our way to recommending that they should be invested with new powers which, if they are to be effectual, must be of too inquisitorial a character to allow of their exercise in private hands.

We cannot adopt the suggestions of the House of Commons' Committee of 1867 as to how the details of the arrangements should be carried out, believing that such technical details can only properly be dealt with by competent professional skill, and that they must be carefully determined under the guidance of the experience gained in the process of change. The same Committee recommend, among other things, that the companies should combine with a metropolitan public body to frame rules for controlling the house arrangements, any violation of such rules being penal; but we believe it would be difficult for any such complex arrangement to be made to work satisfactorily.

243. After mature consideration of this important question, we have come to the conclusion that the constant service system cannot be effectually carried out in London so long as the supply remains in the hands of private companies, and we have explained, in Section IV. of this part of our Report, in what manner we conceive the change may be effected.

In any case, however, such a change must be introduced very gradually, and with the greatest precautions, particularly in the poorer and lower districts; and even with all possible care preparations must be made for meeting considerable loss of water in the earlier periods of the alteration.

Compulsory Supply to the Poor.

244. Connected intimately with this subject is that of furnishing a compulsory supply to the poorer districts.

It has been established by law that the supply of water, being a necessary of life, must not be left optional; for though every arrangement may be made for affording a

proper supply wherever it is demanded, experience has shown that it is necessary in many cases to enforce its reception.

We have reason to believe that the companies honestly do their best to supply the poor, and are inclined to be liberal in their arrangements for this purpose; but they complain of the great difficulties they have to encounter.

The Committee of 1867, after reciting the legislative provisions applicable to this purpose, say:—

"These various provisions of the law would seem to be ample for the purpose of ensuring a due supply of water for all purposes for the inhabitants of the metropolis in every house, but your Committee regret to state that they have hitherto failed to effect this desirable object, more especially in the cases where a proper supply of water is most essential."

They recommend an improved system of inspection, under the auspices of a metropolitan public body, and certain alterations in the manner of levying the rates; but we are of opinion that in this case also, the same complete change is called for as in the case of the constant supply.

Section IV.

GENERAL CONTROL OF THE WATER SUPPLY.

245. In a matter of such vital importance to the health of a large population, we consider that it becomes a serious question in what hands the control of the water supply should be placed.

246. The duty of supplying the inhabitants of a city with water has from a very early period been regarded as a peculiarly municipal function; and the supercession of the municipalities by joint-stock companies is a comparatively modern innovation, assuming the New River Company to be the earliest case in point.

Since this case the private companies have very generally exercised the functions in question; but of late years many towns in England have come to the conclusion that the new practice was a fundamental error, and have resumed the ancient principle by taking the control of the water supply again into their own hands. Manchester, Glasgow, Liverpool, Dublin, Bolton, Bradford, Halifax, Leeds, Rochdale, Preston, and many other towns, are instances where this has been done.

247. We have had Mr. Heron, the town clerk of Manchester, before us, and he has given evidence as to the circumstances under which the water supply was taken into the hands of the corporation. The following are extracts:—

7270. "In 1845 the attention of the corporation was more especially directed to this subject; we were in a most lamentable condition, and it was quite clear that some complete change was necessary. Perhaps I may be allowed to state that about that time the second report of the Health of Towns Commission was published—a commission over which the Duke of Buccleuch presided—and which I have no doubt is familiar to this Commission, for in that report it seems to me the subject is almost exhausted; we found it stated that 'the importance of an ample supply of good water, accessible at a price within the reach of the poorer classes of society, and in far greater quantities than have hitherto been furnished, is a subject worthy of the greatest attention.'"

7276. The report states: "It appears to be generally admitted by witnesses examined before us, who, being "themselves connected with existing water companies, have had every opportunity of observing the effect "of the opposing interests of the companies and their customers, that a copious supply of pure water cannot "be secured to the poorer classes of the community, unless the duty of providing it is placed under the "management of some independent body. It should be the duty of the local administrative body not only "to secure a sufficient supply for all the inhabitants, but, by contracting with or purchasing it of the water "companies, to ensure its regular distribution at a fair remunerating price." Another recommendation was—"With a view of ensuring a sufficient supply and proper distribution of water to all classes, we "recommend that it be rendered imperative on the local administrative body charged with the manage- "ment of the sewerage and drainage to procure a supply of water in sufficient quantities not only for the "domestic wants of the inhabitants, but also for cleansing the streets, scouring the sewers and drains, and "the extinction of fire. For this purpose we recommend that the said body have power to contract with "companies, or other parties, or make other necessary arrangements." A further recommendation was—"We "recommend that as soon as pipes are laid down, and a supply of water can be afforded to the inhabi- "tants, all dwelling houses capable of benefiting by such supply be rated in the same way as for sewerage "and other local purposes, and the owners of small tenements to be made liable to pay the rates for water, "as we already recommended in respect to drainage.' The corporation at that time felt so satisfied that it was desirable to carry out those recommendations within the city of Manchester, that we determined to go to Parliament to take power to purchase the works of the existing company, and to go for a large scheme which we believed would be sufficient for our present and prospective wants. But we determined also to go beyond those recommendations, because we determined, believing that it was only right and just, to introduce the principle of a public rate, and I believe it was the first time that the application was ever made to Parliament to obtain power to levy, in addition to a compulsory domestic water rate, a compulsory

public rate, payable in respect of all property of every description within the city. We applied to Parliament in 1845, and then and by subsequent Acts obtained power to carry out a scheme which is not yet, I am sorry to say, completed. In 1848 we went for a second Act, which was simply to enlarge the scheme which was proposed by the Act of 1847 and since then we have had to go for other Acts of Parliament to obtain additional power, both with regard to the scheme itself, and also for carrying out in detail works within the city and the adjoining districts which we supply."

Mr. Heron remarks that one result of this has been that the corporation have been enabled to carry out a plan of water supply of such magnitude as could not have been accomplished by any private company. He says :—

"I feel perfectly satisfied that we should never have had such a scheme carried out unless we had undertaken to do it ourselves. Besides, the expenditure which we undertook was such an expenditure that it is quite certain no private company would ever have dreamt of encountering; nor was it one which they would have been justified in undertaking. A private company could not have acquired the money. If it had asked Parliament they would not have granted them the powers that we obtained; and it is only by the exercise of those powers that we have been enabled to incur such an expenditure, and to supply, as I think I can show you we do supply, water at a very low price to the inhabitants of the city." 7314.

He then goes on to speak of the advantages to the town:

"You are of opinion, are you not, that the supply of water and of gas to any large town should be in the hands of the municipal authorities?—I think the experience that we have had in Manchester has shown to us most clearly that the advantages are very great indeed of the supply being in the hands of the corporation. 7316–8.

"Are you now supplying water, not only more abundantly, but of a much purer quality, to the inhabitants of Manchester at a less cost than that at which they obtained their supply prior to 1845?—At a very much less cost, and we are giving them an unlimited supply of, as we have always thought, as pure water as is obtainable.

"Does that reduction in cost arise from your mode of spreading the burden of supply over all the rateable property as compared with the charge made by a private water company on domestic dwellings only?—In the first place the public rate goes necessarily in reduction of the charge that is to be made for the domestic supply within the city. That is the first important item, and which is obtained by the power which we possess to rate all property within the city. In the second place, no doubt as the question suggests, we can rate all dwelling houses, whether they take the water or not, (but they do take it, every house within the city takes it,) and this power diminishes considerably the amount which would otherwise have to be charged if you were only supplying, say, half or two-thirds or three-fourths of the houses; the cost is the same, the water is there, the water has been obtained, and it costs no more to supply the whole, assuming that we have got the water, which is the fact, than it would to supply three-fourths or one-half of the dwelling houses.

"I gather from your own experience in the case of Manchester that you are thoroughly convinced of the advisability of all corporations undertaking the water supply themselves?—I am perfectly convinced of it. I think the reasons are unanswerable, and one of the strongest reasons is, first of all, that they may obtain power to rate the inhabitants, which I do not suppose would be granted to any private company; they get power to rate everybody whether they take water or not, so as to spread the expense over the largest possible area, and they get that which after all is one of the objects of greatest importance, and I think so reasonable and so just—they get power to tax the whole of the property within the area with a public rate, which is in reduction of the expense of distributing water amongst the domestic consumers." 7355.

The corporation are stated to have the power of levying two rates, one a public or general rate on all property, which is fixed at 3*d.* in the pound, and secondly, a special or domestic rate upon all dwelling houses, which is 9*d.* in the pound, making in this second class of property 1*s.* in the pound on the rateable value, or about $10\frac{1}{2}d.$ on the gross rental. For the 3*d.* rate no water is specially supplied, but the rate is a contribution for the advantages secured to the whole community by their protection in case of fire, cleaning streets, flushing sewers, &c. The 9*d.* rate is for water actually supplied for domestic use. Water is further supplied for manufacturing and trade purposes at prices agreed upon with the corporation. 7277–88. 7395.

Mr. Duncan, the acting engineer to the Liverpool Corporation Waterworks, says that his experience is most decidedly in favour of the corporate bodies in large towns having the entire charge of the water supply. He considers the question is so mixed up with the general health of a town that it is almost impossible to separate it from that view of the subject. In all those towns in England where this has been done the tendency has been altogether in the direction of improvement. Corporations are more easily influenced than companies who have dividends to draw from their supply of water. 2429.

Mr. Hawksley, however, the consulting engineer to the same works, is not favourable to corporation management, public bodies being he thinks more under external influences, and less inclined to be liberal in their expenditure. He admits that a large scheme of improvement for such a city as London could not be carried out by divided companies, but he would prefer amalgamation. 2564–6.

Mr. Bateman, as we have noticed in our description of his scheme, relies on the assumption by the public of the water supply as the only possible means of carrying out any great measure of improvement. He suggests that for such a purpose London has only to follow the example of various towns, where of late the waterworks of companies have passed into the hands of corporations; and he instances Manchester and Glasgow as the two most prominent cases of success. App. E.

2838. 7127. Mr. Simon speaks of the great power which water companies hold in regard to the health of the populations supplied by them; and states that he feels very strongly that the public requires more protection than it yet has against their occasional malfeasances. He says:—

"This power of life and death in commercial hands is something for which, till recently, there has been no precedent in the world, and even yet the public seems but slightly awake to its importance."

248. The expediency and advantage of consolidating the water supply under public control are manifest on many grounds.

In the first place such a measure affords, we consider, the only effectual means of carrying out, in the metropolis, the system of constant supply. We have stated, under the last head, that we conceive the difficulties of introducing this system would be too great to be efficiently overcome by private companies; inasmuch as the great powers necessary for the purpose could only be confided to some public body who would be responsible for their proper application. The unity of action, and the extent of command that would be possessed by such a body, would enable the difficulties to be grappled with far more effectually than could be done by divided and private companies; the divisions of districts would disappear, and hence the store reservoirs and mains might be re-arranged with a special view to the new system of distribution; and the inhabitants would be much more likely to fall in with rules and arrangements established by a public body having no independent interests, than with those made by commercial companies.

Secondly, this measure would offer the best mode of ensuring a proper supply of water to the poor, which, as already stated, has been found impracticable under the present system. For a public control would involve compulsory rating, under which all difficulties of a financial nature, which are the only ones really formidable, would necessarily disappear.

Thirdly, we believe that the consolidation of the various present interests would tend largely to economy. The fusion of the districts; the more convenient re-arrangement of the distribution; the abolition of the several and widely dispersed centres of action; the uniformity of management; and many other beneficial effects of the measure, would all result in saving.

Fourthly, the transfer would tend to improve the quality of the supply, not only by checking the tendency to general abuses, but in particular by ensuring more effectual filtration, which is greatly needed, and which it appears difficult to enforce under the present system. We have already remarked on the neglect of the companies to comply with the provisions of the law in this respect, and may here add that this neglect calls either for more stringent control, or for a more effectual change. If the frequent examination and testing of the water, under public management, showed at any time that the filtration was inefficiently carried out, the public, instead of uselessly complaining, as heretofore, would have the remedy in their own hands.

Fifthly, the change of ownership would increase the probability of beneficial results from the measures already enacted, or any further ones to be enacted, for the purification of the Thames. It is possible there may be some difficulty in effectually carrying out these measures; and we believe that a public body having charge of the water supply would be far more likely to stimulate efficient action on this point than individual commercial companies, who have little power to interfere in the matter. And if, at a future time it should be found desirable to undertake any large and comprehensive measure for increasing the quantity of water, whether from the Thames basin or elsewhere, or for further improving its quality, such a measure could only be carried out by combined action, of which the consolidation under public control would be the most advantageous mode.

Sixthly, this measure would much facilitate the provision of water for all public and municipal purposes, and in particular for the important object of extinguishing fires. The documents we have printed in Appendix BL. furnish an appropriate illustration of the urgent necessity of some change in the latter particular.

249. But independently of these advantages, we believe the public management to be far more correct on general principles than the supply by joint-stock organization, which is obviously only applicable to those cases in which a fairly remunerative return may be anticipated for the capital expended. But a sufficiency of water supply is too important a matter to all classes of the community to be made dependent on the profits of an association.

We are hence led to the conclusion that future legislation should restore the ancient practice. The various important considerations above mentioned;—the increase in wealth

and rateability of the great centres of population;—and the facility and advantage with which, in the cases brought to our notice where the requisite powers have been conferred, these powers have been exercised;—all point to such a solution of the problem.

250. Under this system it would be necessary to abolish the voluntary buying and selling arrangement now subsisting between the consumers and the companies, and to adopt the plan of compulsory rating as at Manchester, Glasgow, and elsewhere. Two rates should be enforced; one a special or domestic rate on all dwelling houses, the other a public or general rate upon all rateable property.

Such rates would assess all property much more equitably than the present tax upon consumers. The cost of the supply of water for extinguishing fires, and for general public objects, ought clearly to be borne rateably by all ratepayers; and to assess such burdens solely on the customers of the water companies is a manifest violation of all equitable commercial principles.

PART VI.

ON THE SUPPLY OF PROVINCIAL TOWNS.

251. Your Majesty's commands to us directed that, after reporting on the suitability, for the supply of the metropolis, of the sources of water in the high grounds of England and Wales, we should further report "how the supply from the remaining sources may "be most beneficially distributed among the principal towns."

252. In accordance with these instructions, we began to make inquiries as to the supply of some of the provincial towns, and as to the gathering grounds in various parts of the country generally available for water supply. But we soon found that such an inquiry must be one of great magnitude, involving a large amount of statistical and topographical investigation extending over the whole kingdom. We felt that it would be impossible for us to undertake this without further powers, while its prosecution would delay, probably for some years, the more important and pressing question as to the metropolitan supply. For this reason we resolved to complete our report on the latter subject, and to limit our recommendations on the former one to a few general principles.

To aid in these researches we have had prepared an elaborate map of the catchment basins of the various rivers in England and Wales; we have published this map in Appendix BN., and it will form, we believe, a useful groundwork for future investigations.

277. 253. We have received evidence from Mr. Bateman, as to the supply of Manchester and Glasgow, and he has also given us valuable data as to the supplies of a large number of towns in the Lancashire district, illustrating his remarks by the map, Appendix BO.

2097 et seq. 2570–80. 4620. 1381–407. 277–9. 1061 et seq. 4774 et seq. 4964. 5653–5735. We have also had much evidence about the supply of Liverpool, from Mr. Duncan and several other witnesses.

Mr. Dale has given us some information as to the supply of Hull, and we have already mentioned, in Part I., his proposal for bringing water from the Westmoreland lakes for the supply of various towns in Yorkshire and Lancashire.

Some particulars as to the supply of Sheffield are given by Mr. Holmes, borough surveyor, and Mr. Jackson, chief constable.

Mr. McClean describes the works he has constructed for the supply of various towns grouped together in Staffordshire, and which are illustrated by the map, Appendix BD.

254. We have alluded, in Part I. of this report, to the proposal made by Mr. Bateman, that if his plan for supplying London from the hills of North Wales were carried out, his aqueduct might be used for the supply of a large and very populous manufacturing district in the midland counties through which it would pass. Messrs. Hemans and Hassard also contemplate affording a large supply to towns in the centre of England, by their conduit from the Lake district.

255. There are two remarks of a general nature that suggest themselves in regard to provincial supplies.

In the first place, it appears to us that the Legislature should always jealously watch any proposal for a town taking water from a gathering ground at a distance from it, lest by so doing it may deprive other places nearer to such gathering ground of their more natural source of supply. Mr. Bateman has put this argument so forcibly in the case of Liverpool that we may quote his words:—

277–9. "I think that it was altogether wrong that Liverpool should have been allowed to go to this district, because Darwen, Accrington, Blackburn, Wigan, and many other places are large and flourishing towns closely contiguous to the Liverpool gathering grounds, the whole district having a dense population where the inhabitants can only look to this little cluster of hills for a supply of water. Liverpool has put its paw upon that supply, and has very considerably limited the power of the surrounding districts getting an additional supply of water; and I would venture to suggest, as it is a national question, that if Liverpool should be permitted to go to Bala Lake for water, where it may take water without injury to any manufacturing interest, those hills being as it were the great manufacturers of water, the Rivington district should be held liable to have water abstracted from it for the supply of any neighbouring town which could not otherwise get a supply of water."

This argument ought not to be lost sight of in regard to the proposals for supplying London from Wales or Cumberland; for before either of these plans could be approved, it ought, we think, to be conclusively shown that the abstraction of water from these sources

could not stand in the way of the supply of other places nearer to them. In regard to the Lake scheme, this would be, we conceive, a very powerful objection, as that district has already been several times pointed to as the best source of supply for large and growing masses of population in the north and centre of England.

At any rate, when circumstances render it necessary that water should be brought from a distance, care should be taken to include in the scheme the supply of all places along the route by which the water is conveyed. In the case of Liverpool, for example, if water should be procured from the upper Dee, as is proposed, the project should embrace the supply of Chester and all other places on the way.

256. Then, secondly, we would strongly call attention to the remarkable tendency that towns in the manufacturing districts have to arrange themselves in groups. Take for example the enormous group around Manchester, the group of the Potteries, the group of towns immediately to the north of Birmingham, the groups on the Tyne and near the mouth of the Wear, and many other instances.

This tendency ought always to be considered as an essential element of any arrangements for water supply. Such a group of towns uniting together may go for a much better and more perfect scheme than any one of them separately, and the Legislature ought not only to encourage but as far as possible to compel such a combination.

Instances of the favourable effects of such combinations are afforded by Manchester, which sends, or contemplates sending, supplies in all directions radially around the city, and in Staffordshire, where several towns have been successfully supplied in this way by Mr. McClean.

On the other hand, instances of the unfavourable results of a neglect of this precaution have been experienced in some parts of the country.

Referring again to the Cumberland Lake district, it is obvious that it might be made, by a united effort, available for providing an almost unlimited supply for great groups of manufacturing towns in the north of England ; but it is only by a large union of districts that the expense of such a scheme could be justified.

We therefore consider that when any town belonging to a large group, particularly if forming the nucleus of it, comes to Parliament for a water bill, the scheme should be so designed as to include the whole group.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS.

(The figures in the margin refer to the paragraphs, in the body of the Report, from which these conclusions and recommendations are taken.)

257. We may now give a summary of the conclusions we have arrived at on the whole inquiry, and of the recommendations founded thereon.

As to the Plans for obtaining Water from the Mountainous Districts of England and Wales.

§§ 31, 58–64. 258. We are of opinion:—

That Mr. Bateman's scheme is, in an engineering point of view, feasible and practicable, and that by it a large supply of water might be obtained for the metropolis; but that

§ 36. experience warrants great caution in judging of the sufficiency of a gravitation scheme of such magnitude.

That the quality of the water would be satisfactory as regards its purity; but that

§§ 25, 32. there are points dependent on its softness and colour, which might render it less suitable for the supply of the metropolis than the harder water at present used.

That the outlay for the scheme would be very large, amounting, according to the evidence laid before us, to about 11,000,000*l.*; but in the absence of detailed surveys, and in a project involving works of such great magnitude and novelty, and subject to

§§ 33, 34, 35. such large contingencies and elements of uncertainty, we do not consider that it is possible to arrive at any trustworthy estimate of the cost.

That, even assuming the work could be carried out for the estimated amount, the cost to the metropolis of obtaining water by this scheme would be much greater than is

§ 38. incurred by the present plan, and would continue to be so up to any quantity likely to be required within a reasonable lapse of time.

§ 39. That the scheme, if ever brought before Parliament, would probably be strongly opposed by interests connected with the River Severn.

That grave doubts may be entertained whether it is desirable that the metropolis should be dependent on one source of supply so far removed, and which might be liable to accidental interruption.

That great anxiety would be felt as to the formation of immense artificial reservoirs at the head of the Severn Valley.

That as to Messrs. Hemans and Hassard's scheme for supplying the metropolis from the Lake district, the same general remarks apply; the distance is greater, the estimate higher, and the gathering ground more likely to be claimed for nearer supplies.

As to the Quantity of Water available from the Thames Basin.

§ 148. 259. We are of opinion:—

That the River Thames, supplemented, if necessary, by works for storing the flood waters, together with the River Lee, and the water obtainable from the Chalk to the

§§ 82–94. south and south-east of London, as well probably as from the Lower Greensand, will furnish a supply sufficient for any probable increase of the metropolitan population.

That the abundance, permanence, and regularity of supply, so important to a large metropolis, are secured much more efficiently by the great extent and varied geological character of a large hydrographical basin such as that of the Thames, than by the necessarily very much more limited collecting areas that can be made available on the gravitation system. In the former case also the supply streams are self-maintaining, while in the latter the channel must be subject to the accidents incident to its artificial construction.

As to the Quality of the Water from the Thames Basin.

§§ 213–215. 260. We are of opinion:—

That there is no evidence to lead us to believe that the water now supplied by the companies is not generally good and wholesome.

That for drinking purposes the hardness of the Thames water is quite unobjectionable, and in no way prejudicial to health. The weight of evidence seems in favour of hard water, as more free from certain dangers inherent in soft waters on account of their greater solvent power. §§ 165. 174. 213.

That for cooking no important objection to the Thames water has been clearly proved, except as regards the deposit in kitchen boilers, which deposit is easily removed. § 169.

That for washing, and for manufacturing purposes generally, soft water is preferable as more efficient and more economical, but there appears no means of expressing the amount of saving in a money estimate. Looking, however, to the fact that the hardness of the Thames water is moderate in degree, and is still further reduced by boiling, and considering also that the proportion of the whole metropolitan supply used for manufacturing purposes is exceedingly small, we cannot see that this advantage is of sufficient importance to render it necessary to go to a great distance for soft water. § 173.

That the artificial softening process does not appear to be applicable to the Thames waters on a large scale. § 176.

That perfect filtration is highly essential to the good quality of the water supplied; that this process is at present in many cases very imperfectly performed; and that more efficient means of enforcing the provisions of the law in this respect are required. §§ 209–212.

That when efficient measures are adopted for excluding the sewage and other pollutions from the Thames and the Lee, and their tributaries, and for ensuring perfect filtration, water taken from the present sources will be perfectly wholesome, and of suitable quality for the supply of the metropolis. §§ 216, 217.

As to the Quantity of Water likely to be hereafter required for the Supply of the Metropolis.

261. We are of opinion:—

That a probable increase of population to 4,500,000 or 5,000,000 may have to be provided for, though we believe that the time for such an extended provision will be very remote. § 223.

That 200,000,000 gallons per day is the highest demand that need be reasonably looked forward to for the metropolitan supply. § 229.

That the various companies are prepared, with only moderate additions to their present engineering means, to supply a quantity little short of this amount. § 232.

As to the System of Constant Service.

262. We are of opinion:—

That the constant service system ought to be promptly introduced, to the farthest extent possible, in the supply of the metropolis. § 241.

That it cannot be effectually introduced in London so long as the supply remains in the hands of private companies, to whom it would be inexpedient to confide the great powers necessary for the purpose. §§ 242, 243.

As to the general Control of the Water Supply.

263. We are of opinion:—

That it is a matter of vital importance that an abundant supply of water should be provided for all classes of the population, as well as for general public purposes, street watering and cleansing, public fountains, and extinguishing fires. §§ 245–250.

That for these purposes, there should be a power of levying, as at Manchester, Glasgow, and elsewhere, two rates, one a special or domestic rate on all dwelling houses, the other a public or general rate upon all rateable property.

That no trading company could be permitted to levy or expend such compulsory rates, and that therefore the future control of the water supply should be entrusted to a responsible public body, with powers conferred on them for the purchase and extension of existing works, and for levying the rates referred to.

That this plan offers the only feasible means of introducing efficiently the system of constant supply, and for securing a compulsory supply to the poor; we believe that it would tend to economy, to the improvement of the quality of the water, and to ensure the proper provision for public objects and for extinguishing fires; and that it would increase the probability of beneficial results from the purification of the Thames. § 248.

As to the Supply of Provincial Towns.

§ 255. 264. We are of opinion:—

That no town or district should be allowed to appropriate a source of supply which naturally and geographically belongs to a town or district nearer to such source, unless under special circumstances which justify the appropriation.

§ 256. That when any town or district is supplied by a line or conduit from a distance, provision ought to be made for the supply of all places along such line.

That on the introduction of any provincial water bill into Parliament, attention should be drawn to the practicability of making the measure applicable to as extensive a district as possible, and not merely to the particular town.

All which we humbly submit to Your Majesty's gracious consideration.

RICHMOND.
J. THWAITES.
H. D. HARNESS.
B. S. PHILLIPS.
THOS. E. HARRISON.
JOSH. PRESTWICH.

WILLIAM POLE,
Secretary

9*th June* 1869.

ROYAL COMMISSION ON WATER SUPPLY.

MINUTES OF EVIDENCE

TAKEN BEFORE

THE COMMISSIONERS,

FEBRUARY 1867 to DECEMBER 1868.

Presented to both Houses of Parliament by Command of Her Majesty.

LONDON:
PRINTED BY GEORGE EDWARD EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE

1869.

18079.—2.

LIST OF WITNESSES.

1867.

	Page
6th February.	
Mr. John Frederic Bateman - -	1
7th February.	
Mr. John Frederic Bateman - -	10
13th February.	
Mr. George Willoughby Hemans - -	27
14th February.	
Mr. George James Symons - - -	34
Mr. Richard Hassard - - -	44
20th February.	
Mr. Richard Hassard - - -	53
21st February.	
Mr. Thomas Dale - - - -	71
6th March.	
Mr. Robert Rawlinson - - -	81
7th March.	
Mr. Robert Rawlinson - - -	87
Professor John Thomas Way - -	90
Mr. Bailey Denton - - - -	94
13th March.	
Professor A. C. Ramsay - - -	104
Rev. James Charles Clutterbuck - -	107
Mr. Robert Rawlinson, C.B. - -	113
20th March.	
Mr. Thomas Hennell - - -	115
Mr. George Hammond Whalley - -	119
21st March.	
Mr. Thomas Duncan - - - -	122
27th March.	
Mr. Thomas Hawksley - - -	137
Mr. George Eedes Eachus - - -	155
10th April.	
Dr. Lyon Playfair - - - -	156
Mr. George J. Symons - - -	161
8th May.	
Mr. John Simon - - - -	165
Dr. William Farr - - - -	172
9th May.	
Mr. John Thornhill Harrison - -	179
Dr. Edmund A. Parkes - - -	194
16th May.	
Mr. Nathaniel Beardmore - - -	202
Mr. Hamilton Henry Fulton - -	216
23rd May.	
Captain Edward Burstal, R.N. - -	219
Mr. George Whiffen Ewens - -	224
29th May.	
Mr. Alexander Bain - - -	228
Dr. Henry Letheby - - - -	232
Mr. James Muir - - - -	238
30th May.	
Mr. Hamilton Henry Fulton - -	244
Mr. Thomas Orton - - - -	248
Mr. Stephen William Leach - -	250
5th June.	
Mr. George Remington - - -	253
Mr. Arthur Sydney Ormsby - -	257
Mr. James Simpson - - - -	261
6th June.	
Mr. Samuel Furness Holmes - -	273
Mr. John Jackson - - - -	279
Mr. Robert William Mylne - - -	279
Mr. Thomas Hawksley - - -	286
Mr. Charles Greaves - - -	291
20th June.	
Mr. Josiah Firth - - - -	296
Mr. Samuel Jubb - - - -	299
Professor James Alfred Wanklyn - -	301
27th June.	
Mr. John Robinson McClean - -	307
Mr. Jonathan Thorpe - - -	316
Mr. Telford McNeill - - -	320
Mr. Peter William Barlow - -	327

1868.

26th February. Page

MR. JOSEPH QUICK - - - - 328
MR. WILLIAM RICHARD MORRIS - - 333

27th February.

DR. EDWARD FRANKLAND - - - 338
PROFESSOR WILLIAM ODLING - - - 354

4th March.

MR. JOHN FREDERIC BATEMAN - - 356

5th March.

MR. JOHN FREDERIC BATEMAN - - 367

11th March.

MR. JOHN FREDERIC BATEMAN - - 386

12th March.

MR. SAMUEL COLLETT HOMERSHAM - - 406

18th March.

MR. THOMAS CROWTHER BROWN - - 413
CAPTAIN EDWARD BURSTAL - - - 417
MR. RICHARD MEESON - - - 419
MR. JOHN BRAVENDER - - - 421

19th March. Page

MR. RICHARD HASSARD - - - 425

25th March.

SIR BENJAMIN BRODIE, BART. - - - 430
DR. WILLIAM ALLEN MILLER - - - 436

26th March.

MR. JOHN SIMON - - - - 441
MR. RICHARD HASSARD - - - 442

2nd April.

DR. ROBERT ANGUS SMITH - - - 445
MR. JOSEPH HERON - - - - 454

9th December.

MR. JOHN FREDERIC BATEMAN - - 464
MR. NATHANIEL BEARDMORE - - - 477
MR. JOHN TAYLOR - - - - 480

10th December.

MR. THOMAS HAWKSLEY - - - 482

MINUTES OF EVIDENCE

TAKEN BEFORE

THE COMMISSIONERS

APPOINTED TO INQUIRE INTO THE

WATER SUPPLY WHICH CAN BE OBTAINED FOR THE METROPOLIS AND OTHER LARGE TOWNS.

Wednesday, 6th February 1867.

PRESENT :

HIS GRACE THE DUKE OF RICHMOND IN THE CHAIR.

Sir JOHN THWAITES.
Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

JOHN FREDERIC BATEMAN, Esq., examined.

J. F. Bateman, Esq.

6 Feb. 1867.

1. (*Chairman.*) You are, I believe, a civil engineer and a Fellow of the Royal Society ?—I am.

2. And you have for many years given great attention to the question of water supply in various parts of the United Kingdom and elsewhere ?—I have.

3. Will you give us, in the first place, the population of the metropolis in the year 1861 ?—According to the population returns for that year the population within the district of the Metropolitan Board of Works was 2,803,034 persons.

4. What is the present population ?—The present population, taking the rate of increase at which the metropolis in recent years has been increasing, is upwards of 3,000,000 by estimate. Dr. Letheby, in December 1866, gives the population at 3,067,000 in round numbers. The rate of population has been as follows : it has trebled since the beginning of this century, it has doubled itself in the last 40 years, and it is now half as large again as it was 20 years ago ; therefore, at the same rate of increase, in 20 years, it will be half as large again as it is now, and will amount to 4,500,000 persons. I believe that that will scarcely represent the whole population which may be expected to reside in the immediate neighbourhood of London at that time, because the suburbs of London beyond the area included in the district of the Metropolitan Board of Works are so rapidly increasing that they may be taken as forming a part of the metropolis, and ought to be considered with reference to any supply of water.

5. Are you prepared to give us the quantity of water usually set apart for each individual ?—It varies very much, according to the character of the place and the class of inhabitants ; it varies from 15 or 16 gallons a head per day to 50 gallons a head per day, and therefore each town and each city must be taken with reference to its own existing circumstances and what the probabilities are of the supply of water being greater or stationary. Therefore upon that point I think that it would be better to take the actual consumption which exists in London, having reference also to the manner in which it has increased during the last 20 years.

6. Can you give us that information from any official documents ?—I can give it from official documents. In the papers which were prepared by the metropolitan water companies, and which are published in a report of the General Board of Health on the supply of water to the metropolis, which is a public document, and which report was presented to both Houses of Parliament in 1850, the total quantity from the returns of the water companies which was then supplied appears as 44,383,332 gallons per day. In a subsequent report made to the Right Honorable William Cowper in the year 1856 there is this observation : " According to the return furnished " by the several water companies in 1850 it appeared " that 270,581 houses were then supplied with water, " the gross daily quantity delivered having been " 44,383,332 gallons." Those are the figures which I have given you. " It will be observed from the " preceding table that the supply of water to the " metropolis has now reached the enormous quantity " of upwards of 81,000,000 gallons per day, it having " been nearly doubled in the short space of six years." Then I give you a more recent account which is not from an official document, but which has been prepared by the aid of some of the water engineers of the existing companies, and which appears in a pamphlet which your grace I believe has had. There are some tables there which it may be useful to refer to. They are drawn up precisely in the form of the table which appeared in the report to Mr. Cowper in 1856. The estimated quantity of water used, and the amount of outlay, and other figures which vary from the paper submitted to Mr. Cowper, I obtained from the information of Mr. Quick, the engineer of three of the London water-works companies, corrected by personal interview with Mr. Simpson, who is also the engineer of three of the London water companies. I have likewise the opportunity of knowing that, as far as it goes, it is correct with reference to the East London Company, with which company I am professionally connected, they having recently consulted me on their supply of water. According to the information thus obtained, the quantity of water supplied in the year 1865 was 108,000,000 gallons per day. According to Dr. Letheby's returns, which are made to the Registrar-General, and according to a report of Dr. Letheby's in December of last year, the average daily supply for the year 1866 was 92,734,100 gallons. The average daily supply would not nearly represent the actual quantity which on some days would be taken, because not only does the supply increase during the

J. F. Bateman, Esq.

6 Feb. 1867.

year at a very considerable rate, but the irregularity of supply is very great, inasmuch as 15 or 20 per cent. more is required on one day than is required on another day, and, therefore, no doubt the quantity would occasionally considerably exceed the quantity which I have put down. The 92,734,100 gallons was the average daily quantity supplied by the eight London water companies. The Registrar-General's return, from which that return is extracted, which is a public document, gives the quantity for every month. The highest quantity according to that was in September, namely 100,864,971 gallons. For the months of July and August I have unfortunately lost the returns. Probably in July and August, which are the two hottest months in the year, the supply would be greater than that; but you will see very clearly how the supply is increasing. The average supply for the first four months of the year, January, February, March, and April, was 88,285,000 gallons a day, and the average supply for the last four months, September, October, November, and December, was 97,364,000 gallons. Now the quantity of water which may be reasonably supposed to be consumed for all purposes would be as nearly as possible the same during the last four months of the year as during the first four months of the year. There is always less water consumed in the winter months than in the summer months; but if you take four summer months and compare them with four winter months, or four spring months, as you must do if you take the year only, and if you compare the first four months with the last four months of the year it is as fair a comparison as you can make. Therefore you may take the increase at 9,000,000 gallons a day on the average of the last four months, as compared with the average of the first four months, being in the space of eight months rather more than 10 per cent. of increase. If you look at the returns which I have previously given you will find that the increase during the last nine years has been at the rate of 3,000,000 gallons per day.

7. (*Sir B. Phillips.*) Is all that increase from the same sources?—Yes; there has been no alteration of sources within that period, but the annual increase on the average of the last nine years is 3,000,000 gallons.

8. Then is it to be understood that you now get 150,000,000 gallons of water per day?—In 1856 81,000,000 gallons were delivered, and at the present time, whether you take the Registrar-General's return or the estimate which I have prepared from the information supplied by the engineers themselves, the amount is in round numbers rather more than 100,000,000 gallons a day. The 150,000,000 gallons (it is 158,000,000 upon the paper before you) refer to the capability of the existing companies, the water which they have at command.

9. Are we to understand from you that the present absolute supply is 108,000,000 gallons per day?—Thereabouts.

10. And that in 1850 it was 44,383,332 gallons?—Yes.

11. (*Sir J. Thwaites.*) I understood your answer to be that the supply per head differed in different towns?—Yes.

12. Ranging from 15 to 50 gallons per head?—Yes.

13. What in your judgment would be a fair and proper supply, having regard to health and sanitary arrangements?—The present quantity of water supplied to London, divided by the gross population over whom it extends, is 36 gallons per head per day, and I do not think that it would be safe to estimate upon a smaller quantity; indeed, looking at the constantly growing consumption, or waste of water, 40 gallons per head per day for the population of London, including all purposes, would be as little as you ought to calculate for.

14. (*Mr. Prestwich.*) Between 1850 and 1856 it would appear that the increase of supply has exceeded the increase of population?—Yes, but that was an exceptional period. Between 1850 and 1856 very large works were constructed by the existing water companies which enabled them to give a bountiful supply.

15. (*Mr. Harrison.*) Can you give the population in 1850 and in 1856 approximately?—These returns do not give the population, but they give the number of houses supplied; that, however, does not give you the population, because it may not represent the whole. In 1851 you can get the population by the population tables, and in 1856 you can arrive at it by computation; and I do not think that you can get it in any other way. I have not that information at present, but I can prepare it for you.

16. What is the supply per head in Glasgow?—In Glasgow it is 50 gallons per head per day, and in many of the Scotch towns it amounts to upwards of 40 gallons—between 40 and 50 gallons.

17. (*Sir J. Thwaites.*) Does that include the supply for all domestic purposes, including baths?—It includes the supply for all purposes, not only domestic purposes and baths, but trade consumption; and therefore the trade consumption is to be deducted as special trade consumption, which is sold by measure, from the quantity of water which would be supplied to the inhabitants. The net consumption is about 46 or 47 gallons per head per day in Glasgow for domestic purposes and for general sanitary purposes, not including trade purposes. In Manchester the gross quantity of water supplied to about 600,000 persons is about 21 or 22 gallons per head, and of that about one-third, as nearly as can be estimated, is supplied for trade purposes, leaving the actual quantity consumed for domestic wants and general town purposes about 14 or 15 gallons per head.

18. (*Col. Harness.*) Did I understand you rightly that in Glasgow the 46 or 47 gallons per head did not include trade purposes?—That does not include trade purposes; the 50 gallons per head per day does include trade purposes; it includes an enormous amount of waste, and in Glasgow, by due economy and very strict regulations, I have no doubt the consumption can be brought down from 50 to 40 gallons, which would still leave a large quantity. But it is desirable to see the reasons for so large a quantity being used in Glasgow as compared with other places. In Glasgow every house consists of what are called flats; there are scarcely any self-contained houses, and the necessity of waterclosets is absolute, and there being an abundant supply of water from Loch Katrine, the practice has become very general of introducing into houses of as low a rent as 10*l.* or 12*l.* a year, or even lower, a bath as well as a watercloset, so that the quantity of water consumed there is greatly in excess of that consumed in a town like Manchester, where baths are not so generally introduced, and where there is scarcely a watercloset in the houses of the lower classes. The legitimate supply in London ought I think to be as large as the legitimate supply in Glasgow, because you can hardly do without waterclosets; they are almost a necessary appendage to every house in London, and you may have, and probably will have, baths introduced to almost as large an extent in London as in Glasgow. There is no power of restriction, except you make it prohibitory to use water for such purposes.

19. (*Mr. Harrison.*) Taking it generally, do not you find that an increased consumption has been going on gradually in all towns where they have an abundant supply?—Yes; and everywhere where town improvements have extended a watercloset has been substituted for the ordinary privy.

20. (*Sir J. Thwaites.*) Then do you think that in gauging the supply necessary for the metropolis it would be safer to take 40 rather than 36 gallons per head?—Looking to the future I certainly should not estimate it at less than 40 gallons per head.

21. (*Chairman.*) Having paid attention to this subject, you are no doubt prepared to tell us what districts of England or Wales you consider the best from which water can be obtained to supply the metropolis and other large towns?—I think that before you go directly to that point you ought to consider the general

character of the district from which water can be obtained. I think that you ought rather to consider the possibility of getting water from any high lands which might be near to London, and that I presume would include the high lands forming the summit of the drainage ground of the river Thames.

22. Confining yourself to the high districts of the country, will you state from whence in your opinion the best supply of water can be obtained?—According to my opinion (and in that I believe I should coincide with the opinion of most gentlemen who have given attention to the subject) the supply for London, and for every community, ought to be sought for at the purest sources, and where the water is softest, and also where it is most abundant, and where it is most secure from being injured by any operations of agriculture or manufacture, and if those are to be the conditions you must go to the mountains, and you must go to mountains which are not likely to be cultivated; you must, if you can, go to the primitive or the barren formations where little cultivation takes place, and where no population is likely to collect. You must also consider the quantity of water which may be procured, and the possibility, if it is not sufficient in itself at all times in dry seasons, of making reservoirs to store it if there are not natural lakes which will supply the means of storage. The nearest high land to which you can look, from which water can be obtained in a district which will fulfil all these conditions, is North Wales. The rain there, reasoning from like physical conditions, and from actual observations so far as they have extended, is as great as it is in the Highlands of Scotland, and as great as it is in the lake districts of England, with the exception possibly of a particular locality in the lake district which gives an excessive amount of rain from local circumstances which can be easily explained. The extent of ground may be almost said to be inexhaustible from which you can collect water, having reference to the purpose to which you put it, and the elevation at which the water can be collected is such that it can be brought to London at a considerable declivity. I have considered that in laying out any scheme for the supply of London no scheme ought to be entertained at all if you have to go to any distance for the water, and to incur any expense for works of a permanent character which cannot be easily added to or altered afterwards, which would supply you with less than 200,000,000 gallons a day, nor if it were limited to 200,000,000 gallons a day; it ought to be capable of further extension, and looking forward to the future upon so large a question you ought to be able to see your way to obtaining 300,000,000 gallons a day. In the scheme which I have drawn out, and which I prepared as long ago as 1860 and 1862, having thought well over the matter and knowing almost every part of England, and particularly the mountain parts of England and Wales, I prepared a project for bringing in 220,000,000 gallons of water per day, which is double the present supply, and which therefore at the same rate of consumption would be equal to double the present population. That supply might be expected to last for from 35 to 40 years. I selected land in the northern portions of Wales south of Snowdon, south of the very highest part of Wales, lying to the east of Plynlimmon and to the east of Cader Idris, two of the highest mountains. I selected two districts, each capable of affording something more than 100,000,000 gallons of water a day, after giving compensation in water to the streams from which water would have to be collected, but with power of almost indefinite extension existing in the same basin, namely the basin of the Severn, and in the upper part of the river Wye which adjoins. Between the two valleys near Llanidloes there is a low pass by which the head waters of the Wye may be easily diverted into the head waters of the Severn.

23. (*Sir J. Thwaites.*) Can you give us the rainfall of those districts?—The rainfall of the particular district to which I am about to draw your attention has only been taken upon the ground itself since September of last year, but there are many portions of Wales in which the rain returns have been taken for some few years back. There do not appear to have been many meteorologists in Wales, and therefore we are rather short of meteorological information as compared with other parts of the country. In the lake district, Dr. Miller, of Whitehaven, many years ago established, very much with my assistance and that of my friends, rain gauges over a large portion of the lake district, and ascertained the fall there. In Wales, in the year 1865, taking rain gauges which were fixed either within the mountainous district or upon the slopes or tops of the mountains, taking nine different places, as near the ground selected as I could get them, the average rain for 1865, which was almost the driest year in the north of England of which we have any record, was 59 inches. The two districts to which I have referred are those coloured upon this map red and green. The rainfall at Dolgelly, which is just at the foot of the mountains, only at 500 feet above the level of the sea, was 57·59 inches in 1865. There is a place 700 feet above the level of the sea, namely Trawsfynedd, at which the rainfall was 48·18 inches. At Festiniog it was 57·22 inches, that being 600 feet above the level of the sea. At a high point 1,140 feet above the level of the sea, namely Rhiw Brifdir, it was 74·49 inches. At Beddgelert, which is just at the gorge of the mountains, and which is only 330 feet above the level of the sea, the rain was 81¼ inches. At Bettws-y-coed, which is on the east of the Snowdon range, and which is only 70 feet above the level of the sea, the rainfall was 54·13 inches. At Llanberis, which is under Snowdon, and which is 370 feet above the level of the sea, the rainfall was 75½ inches. At Rhayader, which is at the head of the river Wye, getting into rather more open country, and which is 880 feet above the level of the sea, the rainfall was 41½ inches. At Llanidloes, which is 750 feet above the level of the sea, it was 43⅓ inches. The average of all those figures is 59¼ inches. Now, in order to draw conclusions from those facts, as compared with gauges which have been kept in other parts of the country, I have taken nine places as nearly as possible under similar circumstances, but giving the advantage in point of altitude to the mountain gauges which have been kept in the lake district. I have selected these places with a view to make them as fairly comparative as may be. There is one particular locality in the lake district which in one spot last year had as much as 224 inches of rain; that was the Stye, which is close to Seathwaite. That is owing to a particular conformation of country. Wastwater is exposed to the south-west wind, and the hills on each side are the highest hills in the lake district, and the whole of the cloud brought by the westerly breezes is jammed fast in this gorge (*pointing to the map*), and then it goes over the pass at Stye Head, which is about 1,350 feet, and it is then sheltered from the winds and deposits the whole of its contents in the little valley at the head of Borrowdale. At Keswick, at a height of 300 feet, the rain in 1865 was 42·63 inches. At Scawfell Pike, which is 3,200 feet above the level of the sea, it was 49·12 inches. At Derwent Island, which is 250 feet, the rain was 49¼ inches. At Great End, a mountain 2,982 feet high, the rain was 59½ inches. At Brant Rigg, at a height of 695 feet, the rain was 68¼ inches. At Esk Hause, the height being 2,550 feet, it was 61½ inches. At Ambleside, the height being 553 feet, it was 71 inches. At Patterdale Hall, on Ullswater, the height being 450 feet, it was 62 inches. At Wasdale Head, the height being 247 feet, it was 75¾ inches. Those are all situations which, perhaps with one or two exceptions, compared with what I have given you in Wales, are favourable to a large quantity of rain. The average of all those figures is 59·89 inches, as compared with 59·24 inches, which is the average of the gross returns of the gauges in Wales. Now there are certain exceptional places, which I have pointed out, which in 1865 showed the following returns of rain:—Stonethwaite, at a height of 330 feet, was

J. F. Bateman, Esq.

6 Feb. 1867.

84·13 inches; Stye Head Tarn, at a height of 1,472 feet, was 99·85 inches; Sprinkling Tarn, at a height of 1,985 feet, was 103·84 inches; Seathwaite, at a height of 422 feet, was 106·61 inches; and the Stye, at a height of 1,077 feet, was 149 inches; but, so far as we know, there is no locality in Great Britain which gives the same quantity of rain. I believe that in the highlands of Scotland, and in the Welsh hills, particular districts might be selected which would almost give the same return, but the general average of the whole of the remainder of the lake district may be taken in an average year at probably 70 or 80 inches, and in a year of drought, like 1865, at 60 inches.

24. (*Sir B. Phillips.*) What is that as compared with the Welsh district?—The same. I do not believe that there is any difference between the rain falling in North Wales and the rain falling in the lakes.

25. (*Sir J. Thwaites.*) What is the area of the red portion on the map, and of the green portion?—They are each about 66,000 acres.

26. You have so many thousand acres in the red and in the green portions, and you calculate that from that gathering area you will have a given quantity of water. What principle do you adopt?—I am coming to that by and by. I was about to draw attention to the physical character of the two districts. In the lake district of Cumberland we know the actual fall of rain; we only know it in the last three or four years in Wales, under very similar circumstances; but you will observe, that taking the valley of Wastdale and the great valleys which supply the rain, they are gorged in by mountains about 3,000 feet high, and the whole surrounding country is mountainous. The valleys radiate in every direction from Scawfel Pike, the principal ones being open to the south-west. In Wales all the valleys are open to the south-west, and the hills are 3,500 feet high at Snowdon, and nearly 30,00 at Cader Idris, and all the mountains approach 3,000 feet in height. The greatest quantity of rain upon summits which lie between 1,000 feet, and, perhaps, 1,700 or 1,800 feet high, is almost always found on the easterly side of the summit. The rain on the westerly coast is perhaps about 36 inches. It increases at the foot of the mountains, going, say from Liverpool to Hull, to about 40 inches. On the summit of the hills it is from 50 to 60 inches. It is a trifle in excess of that on the eastern foot; further east it is down to 30 inches, and at Hull it is down to 20 inches. I merely draw your attention to these physical features in order to show the conditions which favour a deposition of rain. It may be supposed to be deposited by currents of warm air charged with moisture, impinging against the mountains, and then rising into colder regions, by which means the water is condensed and precipitated and falls in the form of rain, the hills being natural condensers. I will now give the returns of rain since September of last year in the district itself which I propose to lay under contribution for water. These returns are for the three months, October, November, and December 1866, and I may here observe that although one or two of those months in some parts of the country were excessively wet, as in the north of England, and also in the south of England, and in the district of the lakes, yet in Wales there seems to have been scarcely the average amount of rain. In the valley south-west of Llanidloes the rain for the three months was 15 inches. On the hills above Llanidloes it was 24·9 inches. In the valley at Carno it was $12\frac{1}{2}$ inches. On the hills near Can-Office it was $18\frac{1}{2}$ inches. In the valley at Llanwddyn it was $16\frac{1}{2}$ inches. On the hills above Llanwddyn it was 24·8 inches. In Scotland, in the Loch Katrine district, which is a district very similar in altitude and conformation, but not quite so exposed to the west, the rain for those months at Loch Venechar, which is one of the lakes which is put under contribution for the supply of the mills and the streams in the case of the Loch Katrine waterworks, was $17\frac{1}{2}$ inches. For the same three months at Loch Drunkie, which is a little higher up, it was $21\frac{1}{2}$ inches. At the Bridge of Turk, lying at the head of Loch Venechar it was 21·2 inches. On the hills near Glen Finlas it was 16·8 inches. At Glengyle it was 29·2 inches, that being a very wet place indeed. At Loch Dhu it was 27·2 inches. At Aberfoyle it was 20·7 inches. On the hills near Loch Ard it was 23·2 inches. On Ben Lomond it was 30·3 inches. At the Mugdock reservoir, near Glasgow, it was 17·3 inches; and on the hill above the Loch Katrine tunnel it was 27·2 inches. Comparing those figures with the Welsh returns for the same period, taking valley gauges and hill gauges together, we have about $19\frac{8}{10}$ inches in the Welsh district against about $20\frac{1}{10}$ inches in the Scotch district, and therefore the rain in Wales in the last three months of the year 1866 was almost precisely the same as at the Glasgow waterworks. The table before the Commissioners will show the average rain there for many years. The rain at all the places which I have named during that period is shewn in this table, from which may be obtained the average of all the years since 1854 inclusive—$61\frac{1}{2}$ inches, $67\frac{1}{2}$, $59\frac{9}{10}$, $59\frac{8}{10}$, $91\frac{1}{2}$, $82\frac{7}{10}$, 88, $54\frac{2}{10}$, 85, and $90\frac{6}{10}$. The average of those figures cannot be less than about 75 inches—last year it was rather in excess of that—so that we should be justified in taking as the average something like 75 inches of rain for the district in Wales. But as it does not do to lay out waterworks upon an average, we take the two or three driest consecutive years which we can find, and in doing so we should be quite justified in taking 60 inches; that was about the amount of rain in 1865, which was the very driest year during 11 years' returns. Having determined the amount of rain which we may reasonably expect, we then come to the quantity of that rain which is available for useful purposes. We must take the portion which is available to supply the rivers or towns; and from a great number of observations, to which our experience is constantly adding, we know that according to the declivity and the geological character of the country, and the cultivation and the amount of vegetation, the quantity which is taken up by vegetation, or is evaporated or lost to the rivers, varies from about 9 inches to 16 inches, the smaller quantity being of course that where the rocks are the hardest, and the declivities are the greatest, so that the water comes down in floods. If we take 12 inches as the mean between those extremes it will leave us 48 inches as the net available produce of these districts.

27. (*Chairman.*) Then are we to understand that the net available produce from the Loch Katrine district, whence you supply Glasgow, is 48 inches?—The net available produce of the Loch Katrine district is quite 48 inches.

28. (*Sir J. Thwaites.*) Do you gather that from the discharge?—In Loch Katrine we have never put the actual measurement of the water to the test, it being too large a quantity to deal with, but in the Manchester waterworks, and in the Sheffield waterworks, and in the Liverpool waterworks, we know the exact quantity of water falling and the quantity actually discharged, and we know the loss; and it is from those returns, and from similar returns, that I have given you these particulars. The amount of loss varies from 9 to 16 inches, the average being 12 inches.

29. That is by absorption?—Yes. In Manchester we have actually collected and measured in reservoirs 33 inches in the average of two or three dry years. Out of a rainfall of $45\frac{3}{4}$ inches we have actually collected and discharged 33 inches.

30. Is that due to the rainfall, or partly due to springs?—All springs are due to the rainfall; that is measuring every drop of water which flows off.

31. Springs must be different from rainfall; you may have springs which will take the water from a gathering area beyond that in question?—Not in the district alluded to.

32. It depends upon the geological character of the district?—Yes. There are districts to which your

observations will refer, but when you are talking of a large area with large valleys, such as at the Manchester waterworks, where the millstone grit and the lower coal measures are nearly horizontal, and where the water is thrown out by shale beds horizontally, or nearly horizontally, you practically gain or lose nothing, and the observations over the whole of that district show no loss by springs. When you get to a limestone district, or to chalk, or absorbing sands, it may be as you suggest, but in coal measures, and in the primitive measures where the fissures are very small, you may reject everything of that sort.

30. What do you allow for evaporation and absorption?—We only know that we lose so much; we only know that of the rain which falls we cannot turn to useful purposes the whole quantity by a deficiency of from 9 to 16 inches.

34. I suppose that it is a difficult question to determine?—I cannot see how you can determine it. The evaporation from water is about 30 inches. The rain which falls comes down rapidly in the mountain districts, and of all which falls we only lose from 9 to 16 inches. The least amount of loss arises in the steepest districts, and where the formation is the densest, and where there are very few springs. In the Glasgow district there are scarcely any springs, almost all the water which runs off runs off in the floods. In the granite formations there are scarcely any springs, except where the granite is disintegrated and forms gravel beds.

35. Calculating that you have a plus of 48 inches, what will that area yield?—In my calculations I have not assumed 48 inches. I have no doubt that I should be justified in doing so, but I have taken 36 inches.

36. (*Chairman.*) I understand you to say that 48 inches is what is available in the Glasgow district?—Yes, at least, and what would be available in the Welsh district, because I believe that the rain would be the same, or almost the same, year by year. By these calculations I think that we should be quite safe in taking 48 inches as the net available produce of the water in this district; but in my calculations I have only taken 36 inches, and that is only three inches more than we are actually collecting and delivering in the Manchester waterworks, although the average rain will probably be 40 or 50 per cent. more in the Welsh district than it is in the Manchester district. If you will refer to pages 28 and 29 of my pamphlet, appendix B, you will find that on the first branch of the scheme, namely the red district, which mainly consists of the rivers Vyrnwy and Banw, the total acreage of the drainage ground is 66,380 acres, and that the assumed available rainfall is 36 inches, which gives a total average per day of 148,000,000 gallons odd. Then I deduct one-fourth of that for compensation to the rivers, which is 37,000,000 gallons odd, leaving for the city 111,406,000 gallons. If you look at the next page you will find that the total acreage there of the Green district is 64,000, and that there is the same amount of rain, namely 36 inches, and that the available quantity for the town, after deducting compensation, is 107,000,000 gallons odd, making about 219,000,000 gallons as the gross produce of the two districts. Then, having determined the quantity of rain, you must have storage reservoirs for the purpose of holding the water, and that question is to be determined according to the storage capacity and according to the fall of rain, and you must give compensation to the rivers. The compensation usually given in the manufacturing districts, where frequently every drop of water in dry weather is impounded in the night and given out in the day, has been about one-third of that which can be collected. In this district I have only taken one-fourth, because it is not a manufacturing district: there are comparatively no mills, and one-fourth would very materially increase the workable volume of the stream. It may be also useful to have the following information before you:—The quantity of spring water in the driest seasons from ground of this geological formation is about from one-fourth of a cubic foot per second from each 1,000 acres to about three-quarters of a foot per second; half a foot per second would be a full average quantity in a dry season. The floods which come down are enormous. I can give instances of floods, but the floods vary from 200 cubic feet per second to 400 or 500 feet per second from each 1,000 acres, as against a dry weather volume from the same area of about half a foot per second, showing that the floods are 500 or 600 or 1,000 times greater than the mere quantity of water in dry weather; and it is from these floods that the water would be stored for the use of London and for compensation to the mills. The result is that you very materially increase the natural volume of the stream in dry weather, and the beneficial flow of it for the millowners who require it for power. By impounding the water you stop the destructive floods and you increase the useful volume, and that has been the universal result wherever impounding reservoirs have been constructed upon this principle, and compensation upon this principle has been given. Then we have to provide reservoirs to meet the longest droughts.

37. (*Sir J. Thwaites.*) Do you start with any natural reservoirs?—No, with no natural lakes. The longest drought of which we have had any experience in the Manchester waterworks was for 105 days, which was a very unusual period. In a hill district like this a provision for 120 days would cover the longest drought, or the longest succession of droughts ever likely to arise. On the east of England it requires as much as 240 days in order to cover the droughts there, at Newcastle for instance; but in these wet districts where it seldom ceases raining, and where the droughts are not long, 120 days would be quite sufficient, independently of the quantity of water which may be supposed to come from springs during that period. I have provided reservoirs upon that scale, and the quantity of gallons of water per day which could be delivered from the reservoirs which I have provided would be 222,000,000 gallons for 120 days, or 190,000,000 gallons for 140 days, and this is exclusive of the yield of the streams flowing into the reservoirs during that period; if they were taken at half a foot per second for 120,000 acres it would be equal to rather more than 30,000,000 gallons a day in addition. There is therefore provision by those reservoirs for 140 days of 190,000,000 gallons, after giving compensation, and say 30,000,000 gallons in addition from the stream itself, which would make 220,000,000 gallons. Then, if you take the storage reservoirs at 220,000,000 gallons for 120 days, and 30,000,000 gallons as the produce of the stream, you have provision for 250,000,000 gallons of water. Those districts are merely selected because they are the best for the purpose and the most convenient to treat with first. The situation of the reservoirs has been selected with great care. There is one at Llanwddyn, about 750 feet above the level of the sea, which is in the Silurian formation where a reservoir of $5\frac{1}{2}$ miles can be laid out. The Llanwddyn reservoir is 1,000 acres, and it contains 1,089,000,000 gallons. At other places, in similar valleys, reservoirs have been laid out in most excellent situations.

38. What is the width of the reservoir which you say is $5\frac{1}{2}$ miles in extent?—I do not know. The capacity is the thing which you really have to deal with. It will not be more than half a mile on the average. It is a narrow valley. It is as nearly half a mile as possible, and the length is rather more than five miles.

39. What will be the depth of that dam?—76 feet is the height of the embankment. The length is really very short there. It is a very favourable place indeed.

40. (*Mr. Harrison.*) In the evidence which you are now giving are you speaking of this matter from actual sections which have been taken?—Actual sections have been taken of all these reservoirs. Then on the river Banw there are three other reservoirs, all of which have embankments 80 feet in height, and

J. F. Bateman, Esq.

6 Feb. 1867.

they are all 6 feet above the top-water level. On the river Severn, the green district, there is a situation for the very finest reservoir which I ever saw. It contains 150 per cent. more water than Loch Katrine.

41. (*Chairman.*) What is the name of that reservoir?—The Trefeglwys reservoir. There the formation is all very hard clay, and the embankment would be founded in hard clay, the outsides being composed of the driest material in order to prevent slips. The area of Loch Katrine is about 3,000 acres, and the area of this reservoir is about 1,600 acres.

42. (*Mr. Harrison.*) In talking of capacity you talk of the available capacity for waterworks?—Yes. Loch Katrine is 3,000 acres, and we have the power of drawing 7 feet from it. Loch Venechar is about 1,200 acres, and we have the power of drawing 12 feet 8 inches from it.

43. (*Sir J. Thwaites.*) Your capacity is calculated from the point of discharge?—Yes, from the lowest point from which the water can be discharged.

44. (*Mr. Prestwich.*) What is the drainage area of Loch Katrine?—About 23,000 acres, and the drainage area of Loch Venechar, which is our lowest point, is about 45,000 acres.

45. (*Chairman.*) What is the area of this reservoir?—1,600 acres, and its capacity is 2,230,000,000 cubic feet of water. The capacity of Loch Katrine is 910,000,000 cubic feet. On the lower portion, coloured green on the map, I have not surveyed the reservoirs; all the other cases which I have given are cases of actual survey and sections, but the green is an equally good district, as far as eye observation goes, in which to construct reservoirs; geologically it is the same, and as far as the site for a reservoir goes, it is an equally good district with the others. Therefore from these two districts, taking only the low quantity of available rain, which I have taken, namely, 36 inches, which I think is only three-fourths of that which I might have taken, if you add the volume of the streams, during a long drought, you have from 220,000,000 to 250,000,000 gallons, according as the drought may last, from 140 to 120 days. If it is only a 120 days' drought you have a supply of 250,000,000 gallons, if it is a 140 days' drought you have a supply of 220,000,000 gallons. But quite adjoining to this locality, and almost as convenient, lie other districts from which a very considerable quantity of water may be obtained. In the valley of the Severn, on the southern side of the aqueduct, there is a large tract of ground above the level of the aqueduct from which the water may be equally impounded as on the north side. In the valley of the Wye there is a tract of land which may be brought back by a comparatively short tunnel to join the aqueduct. Those are 44,000 acres, and that being two-thirds of the other amount they are capable of supplying about 66,000,000 gallons of water in addition. Then there is a tract of country at a level of above 500 feet underlying the summits of the hills which bound the valley of the Severn which is almost exactly 50,000 acres; the land there is capable of yielding about 80,000,000 gallons a day more, so that you have in adjoining districts an additional quantity which may be collected by proper reservoirs and conduits of about 150,000,000 gallons a day, making a total quantity of 400,000,000 gallons of water. That is a provision which I do not think that you need contemplate. If you provide the means of conveying 300,000,000 gallons, you are, I think, doing as much as may be reasonably expected. In the 250,000,000 gallons I am including the natural volume of the streams, 220,000,000 would be the storage capacity.

46. (*Mr. Harrison.*) Is that northern district so situated that it could be brought into the same aqueduct?—Yes. I have not extended my inquiries as to the actual position of the reservoirs, but I have no doubt that convenient situations for reservoirs can be found there, as have been found in other districts, and the whole of that water may be conveniently brought across the valley to this point (*pointing to the map*). I may say that I have had very large experience in constructing reservoirs, and that there is no difficulty whatever, either from the geological character or the position, or anything here to endanger the construction of an embankment. It is almost an impervious district, and the ground is so close that no water can penetrate. In all the districts (except the one at Trefeglwys, which is all clay, the bottom of the valley there being shale) the material is of the slate formation, and we find no difficulty in constructing reservoirs in a district of that sort. In the district of the Manchester waterworks, which is in the lower coal measures and the millstone grit, and which is very much fissured, we find great difficulty in that respect, and there we have a string of reservoirs, the upper embankment of which is 90 feet in depth. The second is 100 feet, and the third is 80 feet, and we are now constructing two reservoirs below that, with embankments of about 56 feet, which will make five reservoirs, filling the valley altogether for about six miles.

47. (*Sir J. Thwaites.*) Of what material are they constructed?—Of the material of the country. We construct a wall of puddled clay in the centre, the adjoining portions also clay, though not puddled, and the remainder of the best material of the country, generally shale, and the outer part stone. The inside is pitched.

48. What is the width of that embankment?—This (*pointing out the same*) is about 540 feet wide. The slopes are three to one on the inside, and two to one on the outside, and then there is the width of the top bank. This, the Manchester district, is a very difficult one in which to make reservoirs. It is the most difficult district which I ever had to deal with. We have two other reservoirs, one of 76 feet and the other of 60 feet. The height of the embankment of one of the early reservoirs made in Lancashire, the Turton and Entwistle reservoir, is 108 feet. The embankment of one of the Bolton waterworks reservoirs is 86 feet.

49. (*Chairman.*) What is to be the mode of construction of the reservoirs in this district; of what material will they be formed?—There is abundance of material. These reservoirs (*pointing to the red portion on the map*) would be constructed of clay, and the outside of the driest material, namely, shale and rock. In the others, in the bottom of the valley and the sides of the slopes, there is an abundance of clay to make the embankments.

50. (*Mr. Harrison.*) To what extent will those reservoirs interfere with any existing houses or works?—There are no works. There are no residences, except a few houses. In Llanwddyn there is a small village of 30 or 40 houses and a church which would be destroyed. In the Trefeglwys reservoir there is also a small village and a church which would be destroyed, and that is all which would be destroyed. There is not a gentleman's residence in the district, nor a manufactory of any kind until you get to Llanidloes. The district to the north-west of Llanidloes I have not included, because at the head of that portion there are some lead works, but with that exception there are no mineral workings, and none in the district to the north. At Llanidloes there is a mill, and there is another mill at Newtown, but the mill property is very small, and the mill property would be benefited, as far as mill power is concerned, by the system of compensation.

51. (*Chairman.*) Assuming that you destroyed two villages and two churches, what would you propose to do with them?—The churches, I suppose, we should have to re-erect. The villages would be paid for like the destruction of property by a railway company. They belong to somebody, and we should have to pay compensation for them. I do not suppose that there would be any difficulty about that.

52. If you destroyed a village, and did not build it up again, there would not be much use for the church?—Probably not, and the church might be transferred to another district. In the Manchester waterworks we have destroyed a village, and have left a church, which has scarcely any congregation. In the case of

the villages in the Llanwddyn reservoir I have included a cost of 3,000*l.* for rebuilding the church, and for 40 houses, which are mere cottages, 3,000*l.*, and compensation 2,000*l.* If the embankment were made water-tight the pressure would be at right angles to the slope, and therefore the whole weight of water would merely add to the tightness of the bank.

53. (*Mr. Prestwich.*) Have you gauged the streams in this district?—No, because the gauging is of no use, except the dry weather gauge, inasmuch as it is impossible to get the flood gauge unless you have almost hourly measurements, day by day, but I have gauged streams of almost entirely the same character, some in the lake districts, and also in the case of the Glasgow waterworks and in other districts of the country. In speaking of half a foot a second as the natural volume of the stream in dry weather I am speaking from my experience, and what I know to be the case.

54. Have the rivers been gauged lower down?—I do not know that they have. The river Severn is very liable to floods.

55. (*Chairman.*) Are you of opinion that there is great advantage and economy in using soft water?—Yes.

56. Why is that?—Because it produces a lather with a less amount of soap; you use less tea for making tea, and you use less coffee for making coffee. A great amount of evidence has been given upon that subject to the Board of Health, and I believe that it is reliable evidence. I can give you the actual result in Glasgow from the introduction of the Loch Katrine water.

57. (*Sir J. Thwaites.*) Have you any tables to show the quality of the water from this district?—According to Dr. Clarke's test the water is about from one to two degrees of hardness, and this is not in flood, when it is softer, and from which the great body of water would be obtained and stored, but these are the streams in dry weather, when the water is always harder. (*The witness read the following table*):—

TABLE of the ANALYSIS of WATERS collected from the Streams which are proposed to be abstracted for the Supply of the Metropolis from North Wales, by the late Dr. Robert Dundas Thomson, F.R.S.

	Total Impurity.	Organic Impurity.	Total Hardness.
	Grains per gallon.	Grains per gallon.	Degrees.
River Vyrnwy at Pont Hagel	2·60	·72	1·8
River Banw at one mile below Can-Office	2·84	1·16	1·8
River Clywedog at Llanidloes Bridge	6·80	1·40	1·1
River Severn and Afon Dulas at Llanidloes Bridge*	9·92	1·96	1·4
River Severn at Caer Sws	7·24	1·44	2·2
Comparative analysis of other waters:—			
Loch Katrine water, supply to Glasgow	2·35	·605	·8 in the loch.
Manchester water supply	3·33	·680	1·5 as supplied in the city.
Bala Lake	2·08	1·28	·8 in the lake.

* In this sample was included water from the Hafron Brook, or river Severn proper, which stream is excluded from the scheme in consequence of mineral workings at the head of the valley.

58. Was not that statement made some time ago?—But the water does not change.

59. Is there no increase of population?—No. In the Bala Lake, where the water is received from precisely the same geological district, but is impounded flood water to a great extent, the water is of only $\frac{8}{10}$ths of a degree of hardness, and that will probably be the quality of the water when impounded in reservoirs. The Loch Katrine water is ·8 in the loch itself, which is precisely the same as the Bala Lake water, and which may be expected to be the same as the water collected in reservoirs if impounded in this district. The Manchester water supply varies from $\frac{6}{10}$ths of a degree to about 2 degrees in the stream itself, and as delivered in the city it is of about $1\frac{1}{2}$ degrees of hardness. I believe that there is no better supply of water in the world than at Manchester. The water of the Clyde, from which Glasgow was formerly supplied, varies according to weather, between 7 and 9 degrees of hardness, and the water which supplies this city varies between 13 and 15 degrees of hardness. In the primitive formation, in the millstone grit formation, and in some sands, the water is soft. From chalk, from oolite, from lias, and from the new and the old red sandstone it is always hard, and taking the hardness to begin at 5 degrees of hardness I believe it is all above 5 degrees. Therefore it is of importance in selecting water for a great district that you should go to a soft supply. The saving of soap in Glasgow, after the introduction of the Loch Katrine water, which was introduced on one day and never taken from the city again, was as follows:—The manufacturers who used large quantities of soap, and who knew what their consumption was, found that they did the same work better with three boxes of soap than they had done previously with eight boxes of soap, so that they saved $\frac{5}{8}$ths of the soap previously used. I personally inquired amongst some of the large printers, and those who used water in Glasgow, and the saving varied from fully half to $\frac{5}{8}$ths, but the most general computation was that the saving was one half, and I know that the result was better bleaching and purer colours. Then, from calculations made by very careful housekeepers, they calculated that the saving by the use of the Loch Katrine water, to say nothing of the wear and tear of clothes in washing, was quite equal to the rate which they paid for water and upon the north of the river it was then 36,000*l.* a year, so that the saving to the city of Glasgow, upon a population of 360,000 or 370,000 persons, being the population upon the north of the Clyde, amounted to 36,000*l.* a year, or 2*s.* per head per annum. The reports to the Board of Health particularly dwelt upon that point; they obtained a great deal of information, and amongst the rest, information from Dr. Clarke, who invented the particular test which goes by his name as Dr. Clarke's soap test. The quantity of soap taken to produce a lather in a given quantity of London water of 15 degrees of hardness was $30\frac{1}{4}$ oz., and the quantity required to produce the same amount of lather with water of 4 degrees of hardness was $9\frac{1}{2}$ oz., which was less than one-third of the soap, the difference being 11 degrees of hardness. Amongst other inquiries they made many inquiries with respect to cooking by M. Soyer, and he went very largely into the effect upon vegetables, and found that there was an economy altogether in cooking. The result was that two-thirds of the quantity of anything which had been previously used produced as good a result as the three-thirds with hard water.

60. Do you mean after it was boiled?—Yes.

61. Take cabbages?—He goes into the question of cabbage and vegetables generally; it is interesting, and that is his result.

62. (*Chairman.*) What you mean is that it takes less soft water to boil a cabbage than it does hard water?—I mean that you get a better dish of cabbage, of a better colour and flavour, and more nutritious, boiled with soft water than boiled with hard water; and that if you make tea you get an equally good cup of tea with two-thirds of the tea, as with three-thirds. Then Mr. William Hawes, who also gave evidence to the Board of Health, he being a large maker of soap,

J. F. Bateman, Esq.

6 Feb. 1867.

in 1844 estimated the consumption of soap in London at 15 lbs. per head per annum for the wealthy classes, 10 lbs. for the shopkeepers and tradesmen, and 4 lbs. for the labourers, bringing out a result of 200 tons per week. That makes the total quantity of soap used in the year 10,400 tons, which he put at 45*l.* a ton, which I suppose is the wholesale price, making the value of the soap consumed in London 468,000*l.* Dr. Clarke in the year 1850, six years later than that, estimated the consumption of soap used in London at 12,000 tons, being 1,600 tons more than Mr. Hawes estimated it at in 1844, so that the calculations may be said to be both the same. Dr. Clarke estimated the price at 50*l.* a ton for 250 tons per week, and he calculates the soda at 10*l.* a ton; that makes for the soap 600,000*l.* a year. Since that time nearly 20 years have elapsed, the population having increased in that period 50 per cent., and soap may be supposed to have increased also, which would make as nearly as possible 1,000,000*l.* a year as the actual value of the quantity of soap used in London by the inhabitants. Now, if with soft water half the soap will do which is requisite with hard water, there is a saving in soap alone of half a million of money. I merely throw that out as the result of actual observation and consideration. I may mention that in my own house in the country I introduced about three years ago very soft water, equal to Loch Katrine water, in place of hard water which I had before, and the saving amounts to about 4*s.* or 5*s.* per head upon the household soap used in my establishment for house purposes and for washing; it amounts I think to from 3*l.* 10*s.* to 5*l.* a year, and for six months in the year my establishment consists of about 25 persons, and the washing goes on all the year round—that is in soap alone. Those who know the delight of washing in Manchester or in Glasgow in their water, as compared with the London water, will understand the difference. The Londoners and those unaccustomed to the use of soft water can hardly get rid of the soap, for all that you have to do with this water is to touch the soap and you have soap enough to wash yourself perfectly. In many other ways, in the health of the people and in the wear and tear of clothes, there are savings. It is difficult to put the matter in figures, but if they save in Glasgow some 40,000*l.* a year upon a population of 400,000, they would save in a population of 3,000,000 300,000*l.* a year, supposing the difference in the hardness of the water to be the same. In Glasgow the change is from water of about 8 degrees to water of about 1½ degree, and this would be a change in London from water of about 15 degrees to water of 2 degrees, and the saving would be proportionately greater here. I could go very much more largely into this point, but I think that that is sufficient. In the same report of the Board of Health there is the evidence of Mr. Temple, a barrister, who speaks as to the effect of the Paisley water, where hard water was done away with and soft water was substituted, and he says that there various complaints were diminished by the use of soft water. The waterworks manager in the same town gives evidence upon the same point, and he says that from experiment London water requires twice as much soap as Paisley water; and he also confirms the evidence as to the diminution of dangerous diseases.

63. (*Mr. Harrison.*) Can you give the names of any gentlemen who have especially devoted their attention to this question of the economy from the use of soft water?—Yes. You had probably better have somebody from Glasgow who would speak as to the actual result from his own knowledge of the introduction of the Loch Katrine water. I may mention that this year I have a bill in Parliament for the supply of water to Dewsbury, Batley, and Heckmondwicke, which bill is principally promoted by the manufacturers in consequence of the softness of the water. They there get hard water in their own towns, and they find the advantage of soft water to be so great that they would spend almost any money in obtaining it.

64. You have stated that the Loch Katrine water was introduced in one day. What became of the old supply; was it in the hands of the old parties to whom the original supply belonged, or did the town take it?—The town purchased the old waterworks, and took the supply into their own hands.

65. (*Sir J. Thwaites.*) Did not they abandon the old supply?—Yes; that supply was pumped from the river Clyde. The city of Manchester was in the same position; the old supply was in the hands of a private company and it was purchased, and the corporation took it into their own hands, and then the old supply was entirely abandoned. When I say that the Loch Katrine water was introduced in one day, I mean that from the time that the Glasgow people received the Loch Katrine water it was never withdrawn. In Glasgow the new outlay for water was about 1,000,000*l.*, besides the purchase of the old companies, which made the whole cost about 1,600,000*l.* The inhabitants got their water at the same rate as they had previously paid the water company, and therefore they paid no more for their water although they laid out 1,000,000*l.* The saving in pumping, and the increase in the population, and the demand for water were such that after the first two or three years, during which they did pay a little heavier rate, the rate fell to the same price as it had been before the introduction of the new water, and from this time it will be lower. If by the use of that water they saved a sum equal to their whole rate they saved about 40,000*l.*, which at four per cent. was equal to 1,000,000*l.*, which they put into their pockets.

66. (*Sir B. Phillips.*) By whom was that undertaken?—By the corporation.

67. How was that 1,600,000*l.* raised?—By borowing on the security of compulsory rates upon the whole property of the city.

68. Repayable in what way?—Repayable within a given number of years by a sinking fund, but upon debentures raised on the security of compulsory rates upon the whole property of the city. Everybody was obliged to pay, and in the case of the domestic rate there was an unlimited rate on the northern side of the city. A limit was put upon what was called the property rate of I think 2*d.* or 3*d.* in the pound.

69. Do you say that they raised that money at four per cent.?—In Glasgow it was about that amount or rather more. In Manchester the average rate of interest upon the debenture debt of the waterworks which belong to the corporation, and which cost about 1,500,000*l.*, is 4*l.* 0*s.* 10*d.* per cent.

70. How is that money to be repaid?—You pay four per cent. upon the actual expenditure, and then you have the working expenses, and you levy a rate which will be sufficient to meet those two charges.

71. I understand you to say that the Manchester people pay no more for their water now than they did before?—The Manchester people pay a great deal less than they paid formerly, and in Glasgow they pay no more than they paid formerly.

72. (*Mr. Prestwich.*) Can you give us an exact analysis of the water which you propose to appropriate?—I cannot, but it is from the same geological formation, and the water would be the same. I can give an exact analysis of the Glasgow water which comes from the same formation, and also of the English lake water which comes from the same formation.

73. (*Chairman.*) You state that the streams are to be compensated, and that the measure of compensation is well understood?—The principle of compensation is that which I have described in the rivers in Lancashire and Yorkshire and the north of England. Generally there, in consequence of the streams being so much used, and the streams being small, the millers have the power of impounding the night water, and therefore making the whole available during 12 hours, and their compensation is about one-third of the water which is collected. Here, where the mills are very trifling and the stream is very large, and where therefore the millers cannot impound the night water, one-fourth would be a most abundant compensation;

it would increase the volume of the stream in dry weather three or fourfold.

74. In this district are there any fisheries of any kind?—There are scarcely any fisheries. The salmon are stopped by weirs which exist, but since this project became known there has been a stir amongst the fishers; they have denounced it as being a scheme which is going to destroy them. I have, however, a report which was sent to me the other day which shows that no fisheries exist at all now; but there is no reason whatever why the fisheries should be injured. The plan adopted in Scotland for allowing fish gaps and fish ladders may be adopted here, in the case of all the weirs. We have various fish ladders at Loch Venechar, upon the Glasgow waterworks, and we have another at Loch Katrine, and the salmon go up these weirs as they do on the river Forth and other places. There would be no difficulty in arranging the works so that the fisheries might be entirely protected and in fact improved.

75. Do you diminish the quantity of water which would be running in these streams at any particular period of the year?—Yes, in flood we do. The whole principle is that of impounding the floods; and, therefore, immediately below the reservoir, instead of there being a flooded stream there would be an equable stream. Of course a little lower down than that other streams come in and make the river liable to floods, but immediately below the reservoirs there would be a constantly equable flow, instead of a flood at one time and a drought at another time.

76. Are you not aware that those floods are of great benefit in large fishing rivers?—I am. I know that the fish wait for the floods, or, as they are called in Scotland, "spates," in order to go up, but we should only diminish the floods in the lower part of the district, and should not destroy them. There would not be as great a flood as there was formerly, but still a sufficient flood to carry the fish up. But I presume that the fish wait for floods, because in many parts the fish could not go up without them.

77. That is not so?—I have heard so much about salmon fisheries in Scotland that I thought that that to a great extent was the fact in many rivers. The theory (and perhaps it is a correct one) is, that the fish will not go up except there is a spate coming down, but without any difficulty you may make a flood here at any time, if you only get a certain quantity of water. You may make a flood instead of giving the water in regular quantity, and there would be no difficulty in making stairs by which the fish could go up there past the reservoirs.

78. (*Mr. Harrison.*) Is not one of the objections raised by gentlemen who fish with a fly?—There is no difficulty in fishing with a fly. You could produce a better reservoir to fish in and finer fish.

79. You can hardly get the fish up 80 feet?—Yes, you can get them up 80 feet as well as up 8 feet; it is only a greater number of jumps for them. For instance, they go up 80 feet now in five miles, and you can make them do so by a great number of jumps in a shorter distance.

80. (*Chairman.*) Do you imagine that the salmon would go up as readily into your reservoirs, in comparatively still water, as when they were meeting the natural force of the stream?—Just the same. They go into Loch Venechar in great quantities up the salmon ladders, and they go through Loch Venechar. They scarcely ever go into Loch Katrine because there is no gravel bed for them to spawn upon. Loch Venechar is a salmon loch, and Loch Lomond, and also Loch Ness are salmon lochs. You will also consider that where the lakes are large in area in proportion to the drainage ground they are so many regulating reservoirs which destroy the floods.

81. Will you describe Loch Lomond and Loch Venechar, and those lakes; would they have the same description of bottom as you would have?—The salmon do not spawn in the lakes.

82. Would the salmon be likely to be as well off in your reservoirs as in a natural lake?—The trout would be better off, because in newly formed reservoirs there is an enormous amount of food, afterwards of course they become just the same. A lake made by a natural obstruction like a great rock across a valley is in all essential points the same as where there is an artificial obstruction.

83. (*Sir J. Thwaites.*) Could salmon get up 80 feet?—I should not expect them to make 80 feet at a jump. The salmon ladders are made with a slope of about 1 in 10, and the salmon will run up 1 in 10 or 1 in 6 for a very considerable distance, and there are weirs such as the Deanstone weir on the river Forth, which has about 16 feet of fall. There is a salmon ladder there, and logs of wood are put across, and the salmon run up the whole ladder at once. It would be only five times that here. Here is a salmon ladder at Loch Venechar (*producing a drawing*), and the salmon constantly go up that.

84. (*Col. Harness.*) What is the fall of that?—12 feet 8 inches, and when that reservoir is drawn below the top of the lake they cannot go up that weir. Then we make a succession of ladders of different heights, and they go up whatever the height of the reservoir is. Within these walls there are four different ladders at different heights, according to the height of the water in the lake, and the salmon go up there constantly. The outlet of Loch Katrine is a mere gorge in a rock, and there are merely two heights of ladders. In Lock Venechar there are four heights of ladders, and the salmon go through a sluice with a depressing door, and they go up as easily as possible. That does not meet the objection which his grace makes to my statement that a flood is the only condition of a stream in which a salmon will run.

85. (*Mr. Harrison.*) Supposing that the water inside this reservoir were lowered to the extent of 40 feet below the surface, would you propose sluices which should come through?—Yes, if necessary, that could be done. I have made drawings for that purpose in some of the cases in Scotland, but there is no reason why the river itself in its natural quantity in dry weather should not be conveyed round the reservoir, and having got up the stairs into the new channel the fish would be carried right away into the stream above.

86. You in fact would make a byewash?—Yes, which is a very common and very desirable mode of using the water.

87. Do you know whether the upper portions of the rivers which you are proposing to enclose are good spawning grounds now?—They are not.

88. (*Chairman.*) Can you state why?—Upon that point I can only refer to the report of a gentleman who has made a recent inspection of the whole streams, and who has particularly denounced this project; and from his report the progress of the salmon is now opposed by existing weirs.

89. The point is, whether the rivers in this district are or are not good spawning grounds?—I do not know. I am not a salmon fisher, but I should think that they are good spawning grounds. You want a gravel bottom for spawning ground, and although that is not the general characteristic of streams from the Silurian formation, yet I should think that there is a sufficient amount of ground of that description to form good spawning ground. The rivers will be very much of the same character as the rivers which flow from the southern end of the Grampian Hills in Scotland.

90. You are possibly aware that some of the best spawning grounds in Scotland are in the smallest streams, through which in the month of August you could walk without wetting your shoes, and which towards the end of the year have much more water in them?—Yes, I am quite aware of that, but it depends upon the character of the bottom, whether it is a gravel bottom, or a mud bottom, or a hard rock bottom; and the character of the bottom depends upon the character of the formation from which the stream comes.

91. (*Mr. Harrison.*) Is there an association in that part of the country for the preservation of the salmon

J. F. Bateman, Esq.

6 Feb. 1867.

fisheries?—I believe that one has been recently formed, but all that I know about the fisheries is from a report which I have seen.

92. By whom?—I forget the name of the gentleman.

93. (*Chairman.*) You only know that he condemns your scheme?—I only know that he says that it is the most disastrous thing which was ever conceived; at the same time the report speaks for itself, and I believe that it shows that at all events we do not destroy anything in existence, but only something which in anticipation he may make to exist.

94. You are probably aware that the question of salmon fishing in that part of the country has been a subject of considerable discussion?—I am quite aware of that, and I should be very sorry to project a scheme which should do any mischief, if it could be avoided; but as to the fisheries I am quite satisfied that we can make provision for all the fish going up the stream.

95. (*Mr. Harrison.*) By means of a byewash you might be able to take the salmon past?—A long slope from the waste weir would enable the salmon to go up; if you made a slope of 1 in 10 they would go up to any distance, if you gave them a resting place here and there. I had occasion to consider that question before I executed the Glasgow waterworks.

96. (*Chairman.*) Are there salmon rivers between your Glasgow waterworks and the city of Glasgow?—The stream from Loch Katrine runs into Loch Achray, and from Loch Achray into Loch Venechar, and from there it is the river Teith. Above Loch Venechar it is a very excellent salmon river, and just as good a salmon river as it was before. The salmon stairs are now at the outlet of Loch Venechar.

97. How is the water taken from Loch Venechar?—Loch Venechar is a compensation reservoir, and the water from there is discharged for the purpose of increasing the stream in dry weather, and compensating the millowners.

98. The position of the salmon in your Glasgow scheme would not be upon all fours with the position of the salmon, if you carried out the scheme of bringing water from North Wales to London?—It would be precisely the same except as to altitude, because the salmon can go upstairs at an embankment put across a lake, which is nearly the same thing as an artificial reservoir. The water which is taken to Glasgow is abstracted from the river Forth and turned into the river Clyde, and the water which would be abstracted from the Severn would be turned into the river Thames for London. The only difference would be that there would be higher embankments.

99. (*Mr. Harrison.*) To what extent have you the power of lowering the water in Loch Venechar?—Twelve feet 8 inches.

100. What would be the level of your discharge pipes above Trinity high water?—Four hundred and fifty feet within a few feet. I think that there are a few feet of difference. It is 435 feet I think in one case, and 450 feet in the other.

101. Would that be a sufficient height in bringing water to London to give a constant high level service?—It would give us a fall of one foot in a mile on the average. The distance is 183 miles, and that would be 183 feet. Deducting that from 450 feet you have about 270 feet in round numbers above high-water mark.

102. At what distance from London would that be?—At Stanmore, it would be about 10 miles from Cumberland Gate, Regent's Park. You cannot go beyond a certain height, because the intervening country between Bridgnorth and London limits you as to the elevation to which you can go. From the reservoirs to Bridgnorth there is no difficulty; you go along the hill sides and through the hills by short tunnels.

The witness withdrew.

Adjourned to to-morrow at 11 o'clock.

Thursday, 7th February 1867.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND IN THE CHAIR.

Sir JOHN THWAITES.
Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

JOHN FREDERIC BATEMAN, Esq., further examined.

J. F. Bateman, Esq.

7 Feb. 1867.

103. (*Chairman.*) Will you describe to us the mode in which you propose to convey the water to London from the district which you have selected?—I am doubtful whether I have sufficiently explained the mode of collection, and the manner in which the water would be collected in the reservoirs, so as to make you quite clearly understand the whole of that matter. I doubt whether I made you clearly see the probability of the fall of rain which I have assumed. I only take 36 inches out of 48 inches which I believe I could collect. I have since yesterday prepared a table. I have taken various gauges which I might call mountain gauges from their elevation, or from their position amongst the mountains, which have been selected as nearly parallel cases as the means afforded in Wales and in the Lake district, in order to deduce from that information the available quantity of rainfall. I gave you yesterday the returns of nine gauges in Wales, as showing an average amount of fall in the year 1865, which was the driest year of which we have any record, of 59¼ inches. I also gave you the average of nine gauges in the Cumberland Lake district as 59·89 inches. The height of those nine gauges in Wales varies from 70 feet to 1,140 feet above the level of the sea, that is the highest gauge which we have. The Lake guages vary from 250 feet to 3,200 feet. Up to a height somewhat exceeding 2,000 feet in a mountain district, apart from local circumstances, which may create a great fall of rain in a particular valley, it is ascertained from observation that the rain falling is constantly upon the increase; it is less upon low ground than upon high ground, and less upon high ground than upon ground higher still, till you get to an elevation exceeding 2,000 feet, and then it diminishes. I could not get returns of similar altitudes in Wales, but I took from my knowledge of the country a fair comparison between the two. Since yesterday I have made out returns for 1866, and I find that the nine places which I gave you in Wales give an average of 77⅓ inches for 1866, the least rain in those places being 51 inches, and the highest rain being 114½ inches in the course of last year.

104. (*Sir J. Thwaites.*) If I remember rightly, the smallest fall was on the area which you propose as your gathering ground?—The smallest fall was at Rhayader, at the head of the Wye, but I have no gauges at all upon the gathering ground except at Llanidloes, that is directly at the foot of the hills to the east of Plynlimmon, the others are proximate

districts. Then in the Lake district the average for last year of the same nine places as I before gave was 84·66 inches as against 77⅓ inches, the lowest rain in those nine places being 62⅔ inches at Keswick, which in point of position may be said to represent as nearly as possible Llanidloes, and the highest being 102½ inches, which was at Wasdale Head, a favourable place, and which I selected as being as nearly as possible in the same position as Beddgelert in Wales, which is 113½ inches; that shows a remarkable similarity, so remarkable that the deduction is inevitable that there is quite as much rain, or perhaps rather more rain, falling upon the Welsh hills than upon the Lake hills. The circumstances of the position and the mode in which the valleys lie to the sea, and the manner in which they are affected by the clouds are all similar; but there is one point which I do not know whether I sufficiently dwelt upon yesterday, which is very important in considering the probability of collecting water when you have not the actual returns. If you could suppose a ridge exceeding 2,000 feet high you would have comparatively little rain on the east side, it would stop nearly all the rain clouds from the west and the water would be precipitated on the westerly slopes. In the north of England it is well known that a westerly wind is a dry wind on the coast of Northumberland, while it is a wet wind on the west coast, and that a wet wind on the coast of Northumberland is a dry wind in the western portion of the country, although the hills there are not so high as absolutely to exclude the rain. But where you have a range of mountains, the summits of which measure upwards of 3,000 feet, with depressions in the ridge, you get the largest amount of rain in the valleys to the east of those depressions. Wherever the rain-cloud can be gorged up a narrow valley and pressed over a depression like Stye Head, into the head of Borrowdale, then on the easterly side you get by far the largest portion of rain; and with this in view this district is worth explaining a little further. The general course of the ridge is in this direction (*pointing to the map*). Snowdon is the highest point. This is the general direction in a tolerably regular line from south to north. In that ridge there are various depressions, and I believe that if gauges were placed from Portmadoc up to Beddgelert, and then on to Capel Curig, you will find there as large an amount of rain, or nearly so, as you do in Borrowdale. Then there is another depression which runs up from Dolgelly, and which runs down to Barmouth; there is a very large amount of rain there. Then there is another depression at the river Dovey, and there is a gap there, and the water would be precipitated just over this side (*pointing to the map*). On that we have a gauge recently put, which in three months shows 24 inches of rain. Then there is another depression in the sources of the river Dovey here, and another here (*pointing out the same*), and then we get to tolerably high land to this point, with one or two depressions, so that on this easterly side, if properly examined into, rain gauges may be expected to have a very large quantity of rain. That is the easterly side of the general ridge of mountains extending from Snowdon to Plynlimmon, and there is there a large quantity of rain. As you get away from the easterly side the quantity of rain will diminish. I was merely anxious that that should be clearly understood, because in referring to any mountain district you will find that that is so. If necessary, I can show you rather interesting tables which I took some time ago right across England from Liverpool to Hull, over the Manchester waterworks drainage, and over the Halifax waterworks drainage. The Liverpool waterworks afford a very good illustration. The rain at Rivington in the Liverpool waterworks district was 50 inches. The Bolton waterworks are in the first trough over the hill to the east, the trough running pretty nearly south and north. The westerly winds impinge upon the westerly slope of the mountains which form the drainage of the Liverpool waterworks, and in the average of two years the rain there is about 48½ inches. The rain at Belmont in the Bolton waterworks is 53 inches, and that is going eastward. The next trough is the valley from which the Blackburn waterworks are supplied, and there you have a mean of 42 inches. On the first slope of the hill, which is on the westerly side, you have about 48½ inches, then 53 inches, and then 42 inches. Then when you get away over the mountains and right down into the east, you get down to about 30 inches. The Manchester waterworks are formed in a mountain range, the Penine chain of hills, lying between Manchester and Sheffield, commonly called the Backbone of England. The rain at Manchester in 1859 was 38 inches in round numbers. Going eastward the rain at the Denton reservoir, our first reservoir, which is 300 feet above the sea, was 34 inches; at Newton it was 35 inches, and going a little further eastward it was 33 inches. All these places are upon the plain, or nearly the plain. Then we come to the foot of the hills and we get 46⅓ inches. Higher up at the head of the valley, on the west side, we get 53⅓ inches, then 57·64 inches a little further towards the head. On the east side, just over the summit, we get 58½ inches. At the reservoir of the Sheffield waterworks, which is is on the hills more to the east, we get 46 inches. At Penistone we get 39 inches, and at Sheffield 25 inches, showing that the rain is larger on the west than it is on the east; that it increases as you get up to the top, and that it rapidly diminishes as you get to the east. On the line of the Rochdale canal, which also crosses the Backbone of England, in the same way in the year 1848 at Rochdale, which is at the foot of the hills, you get 39$\frac{7}{10}$ths inches. At Whiteholme, on the top of the hills, you get 66$\frac{7}{10}$ths inches. At Blackstone Edge toll-bar you get 67½ inches, and on the east side 66 $\frac{6}{10}$ths inches; but those last three places are almost entirely upon the summits of hills not more than 1,200 feet high. Then when you get to Sowerby Bridge, which is at the easterly foot, though comparatively in the hills, you get to 32·27 inches; and I have a return of the rain at Halifax in the same year, which would be less than that. Then I may refer also to the case of the Glasgow waterworks.

J. F. Bateman, Esq.

7 Feb. 1867.

105. (*Mr. Harrison.*) Are those facts in the form of a table which you can put in?—Yes; I will give in the whole of these tables.

106. What is the summit of the range in the case under notice as affecting the stoppage of the rain clouds?—There are, I think, depressions as low as 700 feet. If you will be kind enough to look at the map at the end of my pamphlet on this subject you will, I think, see them all. Just to the west of the highest proposed reservoir will be found a summit marked, which is 2,050 feet. Then coming southward there is 1,937 feet; then 1,981 feet; then there is a depression of 750 feet; then coming on further south you get an elevation of 1,651 feet; then you get a depression of 800 feet at the head of one of the branches of the Dovey; then you rise again to 1,475 feet, and then you get to the head of the drainage, a little north of Plynlimmon, which is 1,750 feet, and then you get Plynlimmon itself, which is 2,463 feet. Looking at those depressions you ought to have a very large deposit of rain about the centre, following up the valley of the Afon-Dyfi at about that point (*pointing to the map*). If you will be kind enough to turn to the rain returns for the last three months of 1866 you will find that the rain in the months of October, November, and December was 24$\frac{8}{10}$ths inches.

106. At what level?—I have not quite the level of that gauge. The highest return here is on the hills at a height of about 2,000 feet. That is to the east of the Aran Mowddy mountain, and then at the head of the Llanwddyn reservoir, which is about 700 feet, the rain was 16$\frac{3}{10}$ths inches. Then on the hills above Llanidloes, immediately to the east of that upper proposed reservoir under Plynlimmon, the rain was 24$\frac{9}{10}$ths inches, and at Carno in the valley the rain was 12⅓ inches, showing even in that space the rapid decrease which takes place to the east. The average rain, taking the highest and the lowest together, would be about 19 inches on the mean over the whole of that district in three months. I merely wanted to point

J. F. Bateman, Esq.

7 Feb. 1867.

out that in order to show the mode in which the rain is distributed, and that it does not do to deduce the average rain, except with due regard to the physical circumstances of the country.

108. (*Mr. Prestwich.*) What number of days' rain fall in 1865 in this district?—I have not complete returns on that subject, and I have not the number of days on which the rain fell. Many of these are mountain gauges, and we have to get men to make an excursion once a week to take the rain on them; many of them are in out of the way places. Everybody knows Loch Katrine and Loch Lomond, and the district about there, and will remember that to the west of Loch Lomond there are very high mountains in Argyleshire, which form barriers to the rain-clouds which are brought from the Atlantic. We also find that every successive trough or valley to the east has a diminished quantity of rain, and almost every successive range of mountains has a diminished quantity of rain going from the west to the east. Taking the first great valleys you have the Loch Long valley, which runs up to near Tarbet, then you have the Loch Lomond valley, and then the Loch Ard valley, going to the east, which lies on the east side of the Ben-Lomond range, then you have the valley of Loch Katrine, and then you have the valley of Loch Lubnaig. The drainage ground of the Glasgow waterworks is in the valley of Loch Katrine and Loch Venechar that lies to the north and north-east, and is hemmed in by mountains varying in height from about 2,000 feet to nearly 3,000 feet. That is shut out from the south-west by hills immediately adjoining Loch Katrine, which vary from about 2,393 feet to 2,514 feet, with depressions of not more than 500 feet above the level of the sea. Then go to the south-west again to the Ben-Lomond range; Ben-Lomond itself being 3,192 feet high. The rain on the hills upon the easterly side of Ben-Lomond, but on the flanks and the spurs of the same range of mountains, in 1854 was 109 inches at an elevation of 1,800 feet. On the hills between Loch Ard and Loch Katrine, which is the next successive range of hills to the east, at an elevation of 1,500 feet, the rain was 67 inches. On the hills near Glen Finlas, at an elevation of 1,800 feet, it was 62 inches. In 1857 the rain on the first ridge was 85½ inches, on the second ridge 74 $\frac{2}{10}$ths inches, and on the third ridge 48 $\frac{3}{10}$ths inches. In 1859, two years afterwards, it was 92 inches, 85⅓ inches, and 48 inches, and so every year all through. That shows the importance with reference to the collection of water of bearing in mind that it does not do simply to go to hills, but that one range of hills will yield a larger portion of water than another, although they may be in the same general locality and of the same general height. Then I have returns showing the increase of rain towards the heads of valleys, and showing the effect of passes in mountains, and a variety of returns, all of which tell the same story. It would be tedious to follow the matter through, but I shall be very happy to give in all these returns; they are all interesting and valuable documents. I have thought that it was necessary to draw your attention to these facts because in this particular district, in consequence of its being almost uninhabited (there is not a single resident gentleman that I know of in the whole of this district of Wales), there have been no meteorologists and no meteorological observations; the only observations which have been taken have been taken by some spirited individuals during the last three or four years, and from those returns, which are published by Mr. Symons, are the returns which I have given you of the proximate gauges. In the district itself, with the exception of Llanidloes, the only returns are those which I have given you within the last three or four months, and which I have had taken myself. From the actual fall of rain during the same period being as nearly as possible the same as in the Lake district and in the Loch Katrine district, we may fairly deduce that we shall have the same amount of rain in the one district as in the other; that rain in the driest year would leave a net available produce of 48 inches. I have assumed 36 inches as being a perfectly safe quantity, and have provided storage upon that footing. The storage then becomes the measure, inasmuch as it will be quite clear that the quantity of rain falling, and which is capable of being collected, being greater than I have assumed storage for, the measure of your delivery must be governed by the period for which the store will last during the longest drought which you can provide for, added to the natural quantity flowing down the streams during that period of drought. Of course after the rain has run off, all the water remaining in the river is from springs only, which gradually decrease according to the extent of the drought; but assuming half a foot a second, which is my experience, from 120,000 acres or 60 feet a second that is rather more than 30,000,000 gallons of water a day. The reservoirs are capable of supplying for 120 days consecutively 220,000,000 gallons, and if you add to that the natural stream during the same period viz., 30,000,000 gallons, you have 250,000,000 gallons as the produce from this district, which I have particularly examined.

109. (*Col. Harness.*) Those 30,000,000 gallons you would have to give to the watercourse, would you not, you could not avail yourself of them?—Instead of 30,000,000 gallons, which is the average of a drought, we should give a regular quantity of between 70,000,000 and 80,000,000 gallons to the river, so as to double the volume of the river in dry weather.

110. During a drought must you not give to the watercourses from which you have impounded the water the whole of those 30,000,000 gallons, and something besides?—We should give as much again; what I have given you as the supply to London is the residue. If you will refer to pages 28 and 29 of my pamphlet you will find that the quantity of water which is assumed as available, and as to be taken to the city, in the first table is 111,000,000 gallons a day; that line comes after the preceding line which shows the amount which will be given to the rivers, which is 37,000,000 gallons. If you take those two tables together you will find that they represent 218,000,000 gallons for the city and 73,000,000 gallons to the rivers. Now if the average of a drought is only 30,000,000 gallons the rivers will be 2½ times provided for by giving 73,000,000 gallons.

111. One is a calculation based on the rainfall, and the other is a calculation based on the retaining power of the reservoir?—Yes.

112. Your reservoir will contain such a quantity?—Yes.

113. But from that quantity besides what you give to the city you must give compensation?—Yes.

114. Therefore, if I understand you rightly, your reservoir would contain that number of days supply?—The reservoirs contain a supply of water for compensation at that rate. If you will divide the total amount of storage by so many days you will find that it gives 222,000,000 gallons for the city, plus the quantity for the rivers; that is plus 73,000,000 gallons odd for the rivers. In giving that quantity to the rivers we are giving it in lieu of an irregular stream which on the average of a drought would only be about 30,000,000 gallons.

115. (*Chairman.*) So that the rivers are benefited to the extent of 40,000,000 gallons?—Yes; the dry weather amount of the rivers is about doubled, and therefore the available mercantile power of the rivers will be doubled; they will have a regular equable flow during a drought, which will be double the average flow of a drought, and will be perhaps four times the minimum flow of a drought; they will have that quantity day by day instead of having an irregular supply. Then with reference to the collection of the water, of course you cannot always find a reservoir upon a stream quite large enough to hold the water of that particular stream. In another valley you may be able to find a reservoir which is more than sufficient for holding the water of its own district, and in that way the water may be conveyed from another district, and in that manner the reservoirs have been laid out. The upper red mark, the Llanwddyn reservoir will not only

hold its own water but will receive the drainage of the next valley, which is conducted by a watercourse large enough to convey nearly all the produce of the district, and the watercourse has been estimated upon a scale of flood of about 20 cubic feet per 1,000 acres, which is a considerable flood, but not the maximum. 20 feet per second from each 100 acres for 24 hours duration of flood is a very heavy flood. The water from that reservoir I have allowed to flow down the river to a point a little below Llanwddyn, and from there it is taken to the next river, to the next valley to the south, and communicates with the water collected in reservoirs in that valley, and from that point the water is taken to London. In the drainage which is coloured green there is a magnificent site for a reservoir at Trefeglwys, into that the water from the river Carno will be conveyed, and a portion of that coming from the south of that reservoir will also be conveyed by a large watercourse from the lowest part coloured green. I have not yet had the most southerly portion surveyed for reservoirs, but I believe that reservoirs are capable of being made quite as large as necessary, and in very good situations in that district. The discharge pipes of the northerly portion will be at the level of 450 feet above ordnance datum.

116. (*Mr. Harrison.*) That is at Rhyd-e-Gro?—Yes. From that reservoir at Rhyd-e-Gro the discharge pipe will be 450 feet above ordnance datum. At the Trefeglwys reservoir it is 440 feet. The conduit from thence is a little the longest, but there is a sufficient fall in both of them to convey the water to London. Then I propose to deliver the water at reservoirs to be made on the slopes of the hills, or on the hills near Stanmore near London.

117. With regard to the summit level, the greater part of it ranges considerably above the 1,000 feet and up to 2,000 feet?—Yes, the great bulk of it.

118. Comparing that level with the levels of the hills which you have spoken of in the Lancashire district, are they not a great deal below that level?—A very great deal. The summit level of the ground forming the drainage ground of the Manchester waterworks is about 1,900 feet, but the general level of the hills is about 1,500 or 1,600 feet. The mean level will probably be 1,000 feet.

119. Assuming that where you have 700 and 800 feet in passing through these gorges you have a large rainfall on the east side, would it be purely local, or do you assume that it would spread right and left after passing through?—In the rain returns which I have given you the highest returns are upon elevations of about 2,000 feet. There is no doubt that the quantity of water, which is dependent very much upon its being forced through a gap, will be local, but you will find by Dr. Miller's observations in the Lake district that the rain rapidly increases up to a contour of 2,000 feet, and then rapidly diminishes up to the height of Scaw Fell Pike, which is, I believe, 3,150 feet. The mere elevation of ground will increase the deposit of rain.

120. In fact, the whole contour of the country being high really affects the height of the rain clouds?—Yes.

121. The rain clouds have not so much reference to high-water mark as to the general features of the country?—Just so. If the elevation of the country lies within the region of the rain clouds, which may be said to extend to about 3,000 or 4,000 feet, the greatest portion of deposit within that range takes place at from 700 to 2,200 or 2,300 feet. If the mass of the gathering ground lies within that zone, setting aside local circumstances, that will be the elevation which will give the greatest quantity of rain.

122. From your experience of all parts of England, being obliged in this case to arrive at a conclusion by analogy, are you satisfied in your own mind that you have quite sufficient facts to justify you in your calculations upon the matter of rainfall?—Yes, I should consider myself quite justified in assuming 48 inches as certainly collectable and available, but in order to do that I must make larger reservoirs than I have estimated for. I have more rain than I have reservoirs for, as I have laid out the scheme, and as the estimate is that to which I must refer, it is based upon reservoirs capable of collecting and discharging 36 inches, or thereabouts, in addition to the natural stream during a period of drought. If we take 220,000,000 gallons, and add 30,000,000 gallons to that quantity for the natural volume, which is about one-eighth more than the 36 inches, say $4\frac{1}{2}$ inches; that is an actual collection and discharge of $40\frac{1}{2}$ inches.

123. A question was suggested yesterday as to the fisheries, and that these reservoirs would cut off the spawning ground. If you will refer to the green portion of this map, which really is the Severn proper, practically your reservoir cuts off a very small portion of all the different streams branching out of the Severn at that part?—That is so.

124. Taking it again when you come to the red part of the map, there are all these streams branching out and you only intercept a very small portion?—That is so. The river may be restored to a salmon-passing condition by a bye-channel all the way down from the head of the reservoir to the embankment, and then by a long sloping channel to the river again. For instance, supposing that you made a channel of so gentle a declivity that the fish would run up, if you discharged a sufficient quantity of water for the purpose, which would be a part of the compensation water, you could do that; and supposing that you made a series of leaps of no more than 3 feet each, with a deep pool between, the salmon would get up 1 yard in say every 20 yards. But salmon, if they must jump, require a depth of water to jump from. They depress themselves perpendicularly when they are about to take a leap, and strike the water violently with their tail, which enables them to leap, and unless they have a sufficient depth of water they cannot leap.

125. On that point has it ever occurred to you that as your byewash would commence at the very highest point of your reservoir, assuming your reservoir to be lowered 10 or 15 feet, the salmon would almost naturally go into your reservoir, and if they did so how would they get out?—It might be so arranged that when the reservoir was full they could run into the reservoir, or that when the reservoir was down they could go into a side channel.

126. You would stop them at the high point?—At the upper end they would go up the stream to spawn; they would not stay in the lake.

127. How would it be in coming down?—You might stop them from doing that at a certain season of the year. I believe that they go up and down at almost all seasons, more or less, though they generally go up at one season and down at another.

128. You propose to take a large area of water which no doubt would affect the floods in the Severn. Comparing that with the watershed feeding the Severn we will suppose that you take down to Shrewsbury, can you give the watershed which still supplies the Severn down to that distance?—We affect in round numbers 125,000 acres, and looking at the map and comparing the coloured portion with that which would remain untouched as far as Shrewsbury, I should think that we should have four times that amount, or say about 700,000 acres, of which we should affect about 120,000.

129. Do you think that your abstraction from those 125,000 acres, taking it to Shrewsbury alone, would at all practically affect the question of the spates and floods at that point?—It would make big floods into spates; that would be the effect. We should impound of the floods down to Shrewsbury probably one-fifth portion of the district, and if we did that we should lessen the floods by that proportion, or if we impounded the floods by one-fourth we should lessen the floods by one-fourth. One of the most injurious features of the Severn is its excessively heavy floods.

130. I am looking at the matter as a salmon question?—We could always, if need be, if the fishery question were so important as to render it necessary, make an artificial spate or assist a spate at any

J. F. Bateman, Esq.

7 Feb. 1867.

time by a little outlay in reservoirs for that express purpose. Immediately below almost every stream which we affect there are other streams coming in, which would swell the river to the condition of spate in heavy rain.

131. It appears to me that the large watershed which is totally uninterfered with is so great that it will supply plenty of flood water for the whole of the Severn, particularly in the lower parts of it?—If you take the Rhyd-e-Gro reservoir we should intercept the water of this district (*pointing to the map*). Immediately below that there is the whole of this district (*pointing out the same*) which we do not affect. There is the river Vyrnwy running down, and all these streams (*pointing out the same*) would run down, and they would be unaffected; they would be spawning grounds, and would be accessible to fish.

132. I would suggest to you that you have given very important information in this first map, which gives the whole of the water area of the Severn basin down to Tewkesbury. Having that particular object in view, if you could divide it into two or three different districts it would be important?—I will do so. In the Fishery Report, which I referred to yesterday, and which I had not then with me, written by Mr. Alexander Miller, and dated Chepstow, January 14th, 1867, he gives a long report.

133. (*Chairman.*) Who is Mr. Miller?—I do not know but he is employed by the Board of Conservators of the Severn fishery district to examine and to report upon the subject; he goes into a great many particulars. He says, "The inspectors of fisheries in "1861 report that the area of the catchment basin of "the Severn is 4,437 square miles; the length of the "Severn from its source to the sea 178 miles, and the "length of the tributaries 450 miles, together 628 "miles, but this is exclusive of small streams. I have "walked over and inspected these tributaries to the "extent of 404 miles, and have found in them some "of the finest mountain streams of pure water with "gravel fords, and containing the most superior "spawning grounds that could be found anywhere. "But of these 404 miles only 80, as I have before said, "are ordinarily accessible to the parent fish, the remainder being cut off chiefly by insurmountable "weirs, or destroyed by pollutions. The consequence "is that the parent fish have been deprived of their "natural breeding grounds, and compelled to deposit "their eggs in unsuitable places, in deep currents "where the eggs cannot be incubated, or, if hatched, "the young fish would to a great extent be devoured "by other fish, or be lost and destroyed by flood "waters. We may assume that the proprietors formerly possessed a property of some value in these "streams which they could lawfully protect and fish, "and that the mill weirs at various periods have destroyed the value of these fisheries by the erection of "insurmountable barriers across the rivers without "any compensation to the owners, until at last out "of 668 miles there are only 80 miles of breeding "grounds left to which the salmon have access." The river may be said to be not now a fishery river, or scarcely so, if this is the description of it. The great obstruction to the passage of fish is evidently the mill weirs, and Mr. Miller mentions one case of a weir 15 or 16 feet high, where the salmon attempted to leap and were hurled back with violence. Now it would be a very simple thing, and a very important advantage to the river, if those weirs were so made that the fish could pass them, and any injury which we might be supposed to inflict could be a great deal more than compensated by making such arrangements as that the fish could pass at every one of the weirs. Then Mr. Miller, after having reported upon a question which I daresay he fully understood, ventures upon this opinion:—"A scheme has been proposed for "collecting and abstracting water from the sources "of the rivers Verniew, Banw, and other tributaries "of the Severn for the purpose of supplying London. "If this scheme (which I consider a wild one) should "ever be carried into effect, it would be even more "destructive than the loss that has been caused by "the mill weirs, which are capable of being remedied, "whilst the total abstraction of water from these pure "mountain streams, which include about 150 miles of "the finest spawning grounds, would be utter ruin to "the fisheries. I hope, therefore, your board will zealously watch the movements of the promoters of the "scheme." Now a gentleman who is supposed to have read my report, and who comes to the conclusion that there is to be a total abstraction of water, when the stream will be improved as far as its dry weather quantity goes, is not very competent to form an opinion upon the undertaking itself, and when he says that an interference with 150 miles out of 650 miles would be utter ruin to the fisheries I think that his conclusion is equally untenable. I merely point that out to show that the opinion of this gentleman cannot be relied upon on a matter which he is apparently not capable of mastering.

134. Having detailed to us the quantity of water, and the method by which you propose to collect and store the water, it will now be the proper time to give us the manner in which you propose to convey it to London?—I will do so; but I must remind you that I have omitted to refer to two important questions before we leave the collection. The water is in itself probably as pure a body of water as can be collected anywhere. There is a greater absence of peat upon these hills than is commonly the case on hills in similar districts, and the streams generally run remarkably bright, not as bright as in a limestone district in wet weather, but in dry and cold weather they run as bright as from a limestone district and a coa measure district. When they are collected in such very large bodies as is proposed here it is not necessary to adopt any system whatever for clarification or purification. Any colour with which the streams may occasionally be charged is discharged on exposure in these large reservoirs, or by subsidence. Loch Katrine, which is probably as fine a body of pure water as any in the world, and is almost absolutely colourless, is fed by mountain streams, which in summer and in autumn are as brown as porter. I have never seen a darker stream, even from a bog in Ireland, than the river Strowan, which flows into Loch Katrine, and is one of the principal contributors to it on the northern side of the lake, but all the colour is discharged by exposure to the atmosphere in so large a surface, namely 3,000 acres. That is also the case in the Manchester waterworks and in all the other waterworks where the water is collected in a large body, however coloured it is in the first instance its impurities become removed by time and exposure. But here, as in the Manchester waterworks, if necessary, a principle of separation may be most conveniently adopted, by which every stream, no matter how small or how large, is made to separate itself, pure water going in one direction and turbid water in another. The streams, as long as the weather is cold, or as long as they are unaffected by a heavy fall of rain, even in a very wet and in a very discoloured district, are always at that time pure stream water, and perfectly colourless, and they only become coloured on the occurrence of heavy rain which disturbs the state of things and brings down foreign matter, either colouring matter from the peat, or colouring matter from the clay soil, or the soil which has been disturbed by water running over. Therefore, you only have to take advantage of those two circumstances, namely, that the small stream or the stream unaffected by rain is pure, and that the large stream is or may be impure, and you can easily arrange the separation of every stream. I can readily show you how that is done. Suppose a weir to be built across a stream, which is a tolerably large one, with a subterranean passage underneath the top of the weir, and in front of the top of the weir a little slot, which allows communication with the subterranean passage, a small stream drops through that slot into the passage beneath. As soon as the stream is swollen by heavy rain, and the velocity is great, it jumps that slot and goes down the other way, it goes down the weir.

Therefore, the pure water which drops through the slot may be conveyed away by a side channel into a reservoir for pure water, or direct to the place where it is to be supplied, and the turbid water going down the weir, and so down the river course, may be stored in reservoirs set apart for that purpose, where it may settle and bleach, and ultimately become pure enough.

135. (*Sir J. Thwaites.*) Will not that arrangement carry the water in a mixed condition?—No, it separates it perfectly. When the water is pure it will be received in the subterranean channel. The slot is so arranged that a small stream just drops through it and is conveyed away by a subterranean channel, but the moment it is swollen, and when it is turbid, it jumps that slot.

136. (*Col. Harness.*) If I understand you rightly you would only receive the pure waters which come down in seasons of quiet and would not save the flood waters?—We should save both. This is a plan of the Manchester waterworks (*producing the same*). This upper reservoir is a reservoir for flood and turbid water; the second reservoir, next below, is also a reservoir for turbid water; the next below that is a reservoir for pure water, and then all the reservoirs from there to Manchester are reservoirs for pure water. The turbid water flows into the two upper reservoirs (*pointing out the same*); the pure water is carried round them, and is either taken direct to Manchester, or if it is more than sufficient for Manchester it is discharged into other reservoirs. The turbid water is stored for compensation for mills, and after it is sufficiently clarified it is also taken to Manchester. I will now show you the actual thing in operation. This photograph will show you one of the larger weirs constructed upon the Manchester waterworks (*producing a photograph and explaining the same to the Commissioners*). That arrangement wants no attention, it never goes wrong, and it acts perfectly. It was originally designed with the view of having a little flap in front of the slot, which, as the stream diminished should be also diminished, but in practice we find that that is not necessary. The slot is well proportioned for its purpose, it receives all the pure water, and all the turbid water goes over. Therefore here, in the scheme before you, you can always separate the water in that way if necessary (which I do not think would be necessary), and you can devote some reservoirs to the storage of pure water and some to the storage of turbid water. Then, again, we find that where water is stored in large quantity derived from this geological formation it requires no filtration. There is none in Manchester, there is none in Halifax, there is none in Glasgow, there is none in Blackburn, and there is none in almost all the large waterworks which I have constructed, but we strain the water through copper gauze in order to prevent the admission of any extraneous matter, and those gauze strainers are so arranged one before another that they can be taken out and cleaned from time to time, and everything can be prevented from entering the pipes. Then the service reservoirs, in order to prevent vegetation, must be at least 15 feet deep if uncovered; at less than that depth vegetation takes place, and upon the decay of vegetation animalculæ occur, which must be prevented from entering. In the Manchester waterworks our service reservoirs are from 18 to 20 feet deep, and we never see a particle of vegetation, and they have now been at work for about 14 or 15 years. That water is derived from the millstone grit. In Glasgow, in the same way, our service reservoir is deep, and we have not a particle of vegetation, and where the current of the river is tolerably deep no vegetation takes place. I have a drawing which will show you the arrangement for straining the water before it enters the pipes. This is one of the service reservoirs at Manchester, it is 18 feet deep at one end, and 20 feet at the other (*the witness explained the same to the Commissioners*). The water is brought from the hills and carried up the centre embankment of duplicate reservoirs to the extremity of the service reservoirs, where it is admitted to each reservoir, and then it circulates through the whole of the service reservoirs, and is passed through strainers to the pipes which carry the water to Manchester. In front of the pipes there is a basin which is covered over, it being a sort of tank, and there are vertical pillars in which the strainers are fixed, through which the water has to pass. The straining frames are divided into small compartments, which can be renewed from time to time, and as one frame is taken out another is put in behind it. They are taken away and washed, and are brought back again, and it answers the purpose perfectly. The water is delivered wholly free from floating matter. The same arrangement is carried out in Glasgow. As to the size of the wire gauze of the strainers at Manchester, there are 60 strands to the inch, but that is rather finer than is necessary. I believe that about 40 strands to the inch would practically be quite sufficient.

137. (*Mr. Prestwich.*) I see that at page 30 of your pamphlet you give a rough analysis of the waters flowing down the different streams, separating the organic impurities from the inorganic impurities. The organic impurity in those streams appears to me to be very large in proportion to the inorganic impurity. Can you account for that in any way?—That is not a large amount, practically both the Loch Katrine water and the Manchester water have very nearly one grain of organic impurity. The river Vyrnwy only has three-fourths of a grain, and the river Severn at Caer-Sws has 1·44, and there is 1·96 grain of organic impurity at Llanidloes Bridge; but that is taken at Llanidloes Bridge where there are some lead works, and there is a stream there which I reject. The 1·96 includes what was coming down from lead works worked in that valley, and which I have consequently rejected. There are two or three mills there, and also the sewage of Llanidloes, and therefore that 1·96 ought not to be taken as a test. The others would vary from 1·44 down to three-quarters of a grain, the mean perhaps being one grain. Bala lake has $1\frac{1}{4}$ grain of organic impurity. Bala lake may be said to be a fair sample of the water to be collected, because that is the stored water of the district. But then Bala lake has been formed by the detritus which has been brought down by another river, filling the valley and making a sort of gravel bed, over which the water cannot escape. A very great amount of detritus is brought down there, and has filled that valley with gravel, and that forms Bala lake; and therefore at the outlet of Bala lake there is shallow water, which may account for the great amount of organic impurity.

138. It is much greater than that of the Loch Katrine water; it is double the amount?—Yes, but there is no reason for that.

139. At what period of the year was the water for your analysis collected?—I am not quite sure, but I am told that it was in May. The Manchester water supply has only two-thirds of a degree of organic impurity, and the Loch Katrine water has about the same; and there is no reason whatever why the organic impurity in these waters when collected in reservoirs should be larger than in either of those cases.

140. (*Col. Harness.*) Is any measurement taken by which you determine the quantity of water consumed in Glasgow and in Manchester?—In Glasgow the water is conveyed from Loch Katrine by a covered conduit; it is passed over a gauge weir as it enters the service reservoir. The actual capacity of that reservoir is known to every inch in depth, and the quantity entering and the quantity either increasing or diminishing in the reservoir is daily registered, so that we can ascertain the daily consumption in that way. The measurement is determined by the water flowing into the reservoir, and the quantity contained at any time in the reservoir.

141. Is the reservoir perfectly tight?—Yes. This photograph shows the service reservoir of the Glasgow waterworks (*producing the same*) and the gauge over which the water is gauged is shown. It then goes into the smaller reservoir and it is then gauged again. That shows the actual amount of water entering; then

J. F. Bateman, Esq.

7 Feb. 1867.

if the reservoir lowers in the course of the day it is taken.

142. It is still subject to evaporation?—Yes, but that is not very much; it is a trifle more than one-tenth of an inch in the hottest day in summer, when the weather is most suitable for the absorption of moisture. In Manchester the same process is followed; the water is admitted into a basin where it is gauged and passed into the service reservoirs, and the quantity contained in the service reservoirs is known, so that there can be no question as to that matter.

143. (*Mr. Harrison.*) Were these waters analysed by anyone but Dr. Thomson, who is now dead?—Not for me. Dr. Thomson is, I think, the only person who analysed the waters. We had in other places an enormous number of analyses made.

144. From these Welsh mountains?—No, not in the Welsh mountains, but in mountains of a similar geological formation. The waters are so similar when they come from the same geological formation, and from the primary rocks especially, that the analysis of the highland loch water may be taken to be the analysis of the English lake water or of the Welsh lake water.

145. (*Sir J. Thwaites.*) Has not Dr. Odling made some analyses?—It is very probable that other chemists have made analyses. In order to show how almost identical these waters are I have before me some analyses by various persons, and particularly by Dr. Allen Miller, and by Mr. Penny and Mr. Redwood. The water supplied to Whitehaven, that being from an English lake, contains of organic matter ·46 grains, and of fixed salts 1·60 grains, being a total of 2·06 grains. The Loch Katrine water contains a total of two grains, the organic matter is ·52 as against ·46, and the fixed salts are 1·48 as against 1·60. You will find that the Bola lake contains 2·08 of total impurity, of which the organic impurity appears to be greater than in the other cases, but there is no reason why it should be so.

146. (*Chairman.*) Will you state the mode in which you propose to convey the water to London?—In conveying the water from the hills to London I do not know that I can better describe the mode in which the water is to be conveyed than by giving you a description of the manner in which it is conveyed from Loch Katrine. The first 11 miles or thereabouts of the district on the Glasgow side of Loch Katrine consist of clay slates and mica slates, which are almost impervious to water, and of very great hardness for the most part, and if I have any credit at all for executing the Loch Katrine waterworks it arises from the geological knowledge which I possessed. I saw that everybody who had gone to Loch Katrine before me had missed his way in proposing to make conduits upon the surface of the ground. There was no clay in that part of the country and no means of transporting materials, but they had rocks which, if they could once bore a hole through, would be as lasting as the hills themselves, and perfectly water-tight. I therefore saw that we might sink any number of shafts or drive tunnels without the danger of being troubled with water, which is the great element of difficulty and cost in the construction of tunnels. I accordingly determined to drive tunnels for the greater part through those geological measures, driving from valley to valley, and never having any long tunnels if I could avoid it, but having short tunnels from valley to valley, so that you might come out in the valley and discharge your materials from these various outlets. Upon that system I made the works, and I am quite sure that it was the best, the cheapest, and the most durable method; consequently we had, I think, 70 different tunnels of comparatively short lengths. Here is a section of the Glasgow waterworks. We commence with Loch Katrine, and we have first of all boldly to face a hill which rises above the level of the lake at the point where we cross it, about 500 to 600 feet. We then get out into another valley, and then we have a series of short tunnels which have been driven. All these darker portions of colour are actual tunnelling, and all the lighter portions are cut open.

147. (*Sir J. Thwaites.*) Through what material is this?—Through mica slate. Then we get into a desperately hard country, but they are short tunnels. All the darker parts are tunnels, and all the light parts are "cut and cover," as it is technically called, till we get to a valley where we have syphon pipes across. For the first six or seven miles we go along the rough sides of the mountains till we get upon the summit of a ridge which separates one valley from another, and then we have to carry the water across by wrought-iron aqueducts till we get to a deep valley, which we cross by syphon pipes rising to the other side; and then we proceed with the same description of tunnels till we get to the old red sandstone, where I was afraid of water, and there I avoided tunnelling as much as I could, because I was afraid that I should be drowned out with water. There are cast-iron pipes across the vallies with a fall of five feet in a mile. Through all the upper part through the slate formation there is very little more to do than to tunnel, making a hole of the necessary size. Wherever the rock was sufficiently hard to endure exposure, it was merely shaped out to the proper size of tunnel. Wherever the material was soft and required lining, it was lined, but there was very little lining till we got out of the clay-slate formation.

148. (*Sir B. Phillips.*) What was it lined with?—With brick or stones, as the material was best at hand. The fall is 10 inches in a mile, and the size of the conduit is 8 feet high by 8 feet wide (it is not circular), and it is capable of conveying at 6 feet 6 inches in depth 50,000,000 gallons of water per day, the quantity which we are entitled to take from Loch Katrine. When we got to the valleys we crossed them by syphon pipes, allowing 5 feet fall in a mile. I can show you drawings of the aqueducts. This (*producing a photograph*) is one of the aqueducts.

149. (*Sir J. Thwaites.*) There are stone piers?—Yes. Here is another photograph (*producing the same*); this shews an aqueduct in course of construction. Approaching the aqueducts which are coloured dark red, we built the aqueduct of a stone embankment, and upon that we put a cast-iron trough, and then we have a wrought iron tube a little lower than the trough for the purpose of securing that the trough shall always be wholly immersed in water, so that there shall be no unequal contraction by a hot sun on a summer's day.

150. What is the object of covering this portion (*pointing to the photograph*)?—Because it is the strongest form, and also to prevent the sheep from falling in, and the snow drifts.

151. (*Sir B. Phillips.*) What is the distance from Loch Katrine to Glasgow?—About 35 miles. The cast-iron troughs are not covered. This (*producing another photograph*) is a drawing showing the work in course of construction of this bridge (*pointing out the same*).

152. (*Sir J. Thwaites.*) How many pipes have you?—One four-feet pipe, with 5 feet fall in a mile, conveys rather more than 20,000,000 gallons in a day. They have used our 20,000,000 gallons, and we are now putting down a second pipe conveying 20,000,000 gallons more.

153. Your tunnel through the rock is for the full quantity?—Yes, and the wrought-iron troughs are for the full quantity. The cast-iron troughs were made 4 feet 6 inches high, and by increasing the depth they will take the full quantity.

154. Supposing that a pipe wants repair, what provision have you?—There is ample provision for that and for all contingencies. This is another photograph (*producing the same.*) I believe that all the people in that part of the country thought that I was utterly mad in carrying a line of conduit there, and I have frequently stood upon this summit, and did not wonder that the people thought so; it is about the roughest country in appearance to pass through which anybody can conceive. That photograph was taken during the working. Almost turning your back

upon it, and looking forward towards Glasgow, you look over a totally different character of country from the different geological formation, one being over the clay slates and the other over the old red sandstone. It is a desolate district of 5 or 6 miles. After passing through that old red sandstone formation, we come to a long depression of something like 2½ miles across a river, and across a railway, and that is all done by syphon pipes. The pipes have to bear that amount of pressure. In one or two cases we had to cross over railways, and we adopted that plan of putting the pipes upon pillars.

155. In these cases do you thicken your pipes in order to resist the pressure?—It required no increased thickness.

156. (*Col. Harness.*) Have you used a single line of pipes?—We had a single line of pipes in the first instance, and we are now putting a second line of pipes. Then we have a large service reservoir near Glasgow, which is sufficient for supplying the city for about three weeks without any assistance from the hills.

157. (*Sir B. Phillips.*) Are these works inspected from time to time in any way?—Engineers are constantly upon the spot. These works may be literally said to have cost nothing since they were constructed, except the cost of inspection and looking after them. They are very successful. There are various other aqueducts. In a stone country we build stone aqueducts. I may state that in driving tunnels through this formation it is very slow work. In one part for a considerable distance we only accomplished 3½ yards in a month.

158. (*Mr. Prestwich.*) What is the elevation of the reservoir?—About 313 feet above the Clyde at Glasgow. Loch Katrine is 363 feet above the Clyde at Glasgow, and we therefore lose 50 feet in conveying the water. Tunnelling, where you have short tunnels and where you can bring out the work to daylight at short intervals, is perhaps the cheapest and the best and quickest way of getting through a country of this sort. Where you have long tunnels, and at a great depth below the surface of the ground, you get into great difficulties. The Loch Katrine tunnel, which is 2,325 yards in length, although not the longest, was at the greatest depth below the surface of the ground, and we had five shafts at about 450 to 500 feet in depth. Four of those shafts varied from about 110 to 120 yards in distance apart. We had altogether 12 shafts and two loose ends, which made 26 faces at which we could work, there being two faces at each shaft. The work was commenced in the spring of 1856. The work was completed, and the water passed through, it being opened by the Queen in October 1859, the time occupied being about 3½ years from first to last. But in order to complete the work within that time, we had to sink a great number of shafts. The deeper shafts, those of about 450 feet in depth, took us upon the average from 20 to 22 months to sink, and then we occupied about three or four months in driving, but it was all driven through in 2½ years. But then we had to shape and line the tunnel, which took a great deal of time. When you get into great depths you can hardly get through a work of this sort in any reasonable time, because the shafts take you a long time to sink. Here you have an instance where, in order to complete the work within the period of 3½ years, and where the tunnel in this formation was only 450 feet, as far as the shafts were concerned, below the surface of the ground, you had to sink a shaft at every 200 yards, the deepest and most costly shafts being within 110 to 120 yards from each other, and they took about 22 months to complete before you could commence the tunnel itself. The Mugdock tunnel was through basalt, which is not so difficult by any means to drive through as the Mica slate. There the shafts were fewer in number, and not so deep, but that tunnel took us a longer time to make, in consequence of the less number of shafts than the Loch Katrine tunnel itself, but they were both completed at about the same time.

I have, therefore, in laying out a conduit from the Welsh hills, taken advantage of all the experience and knowledge which I have acquired in the construction of the Loch Katrine works, as well as other works, although that is the largest example, and I consequently have endeavoured as long as I was in the hills to adopt the same system, and till you get into the open flat country there is no difficulty. I do not consider a short hill any difficulty. The conduit passes along the slopes of the hills and spurs of the mountains, excepting one or two ridges which it must cross. There is the Wenlock range. From the reservoirs themselves upon the two branch conduits to their point of junction the work is of a very similar character to that of the Loch Katrine works. We go upon the slopes of the hills, tunnelling through the great headlands, and always avoiding being much above the surface of the ground at any point, so as always to have the watercourse in secure ground, and where we cannot avoid it we cross the valley. For instance, above Welshpool on the road to the point of junction near Marten Mere, we have to cross the river Severn proper with a syphon pipe, and from the Trefeglwys reservoir we have to cross the Severn. After we have crossed the Severn we adopt the same principle as in the case of the Glasgow Waterworks. I have not prepared an accurate section the whole way, but the whole country has been walked over, and the line determined. There are no Ordnance maps in that part of the world, showing the level, but there are a great number of railways and canals and so on, from which the levels at certain points may be fixed, and by the aid of those, and with the Aneroid barometer, and walking over the whole country, we have determined the line of route to be taken, and I am satisfied that within a very trifle the route marked there, until we get to Bridgnorth, is as nearly as possible the line which upon a more accurate survey would be taken, and at all events we have allowed sufficient for any possible deviation. When we get to Bridgnorth we have to pass the river Severn at an elevation of something like 300 feet above it, and we then get upon almost the summit of the country, and we get into the swelling features of the centre of England, where it is much more difficult to find our way, and there probably we may find upon survey, that here and there considerable improvements might be made upon the line which has been adopted. After passing Bridgnorth we go a little below the summit of the country till we come to the river Avon valley which we cross below Warwick, by a deep depression, and then we get as nearly as possible to the summit level of the drainage of the Thames basin. We cross it several times, and that is nearly the summit of the country in the centre of England, and there are great swelling features so that it is difficult to determine the exact way, but as nearly as we can tell, this is the line to be taken. A conduit of this nature is not like a railway or a canal. A railway may be made to go up any hill, or down any valley, at an inclination, and the same with a canal by locks; but a conduit for conveying water from one given point to another by gravitation, must have its regular inclination of so much a mile, and it must follow the contour of the country. If it comes to a hill which it cannot get over, it must go through it, and if it comes to a valley where the levels do not suit, you must either bridge it or it must go by syphon pipes. It is therefore fortunate if you can get a line which will avoid difficulties, especially the difficulty of going through a very populous country, which it is desirable that a conduit of this sort should not do, and the difficulty of going over a coal field. It so happens that in this line you absolutely avoid everything of this kind. You have about a mile of coal field, but the coal is not worked; that is the whole which you have between the reservoirs and London, and that occurs just to the west of Bridgnorth. You go through no town at all. Newtown in the Valley is the only town which you may be said to touch. You go near towns, but you avoid the towns themselves. At Bridgnorth you go about a mile above. You go very close to

J. F. Bateman, Esq.

7 Feb. 1867.

J. F. Bateman, Esq.

7 Feb. 1867.

Newtown. At Montgomery you go a mile away. Between Montgomery and Bridgnorth it is a desolate country; from there you do not come near any town till you get to Bromsgrove, and there you get to the north of the salt district. You are to the south of the midland coal field, and therefore you are on perfectly sound ground. From there you go two or three miles below Warwick, and get into the open country, and you do not go near another town till you get to Banbury, which you are not very far off, and till you get to Berkhampstead, and on the line which the London and North-western Railway traverses, to near Stanmore. I can show you a section as nearly as we can make it of the portion from Bridgnorth forwards. I can in the same way prepare a section from Bridgnorth to London.

I may say that I selected this district with a perfect knowledge of what every other part of the country could do. I was aware of the vast quantity of water, and about which there can be no kind of question, in the Lake district, and the elevation of the Lakes; and I knew that those Lakes from which water could be obtained were not higher than the sites of reservoirs, which could be formed just as large as Lakes, and better than Lakes, because you could make them hold more water in the same area in the Welsh hills. Therefore, not only with reference to distance, but with reference to inclination, it was most important to get the water which you wanted at the nearest point. The backbone of England is not only now largely drawn upon by a great many large towns on both sides, in Yorkshire and Lancashire, but it neither possesses the facility for constructing reservoirs, nor the vast amount of rainfall, nor the large area of drainage which for the metropolis is necessary, nor ought it to be tapped because it is, in fact, the natural resource of all the manufacturing towns in Lancashire and Yorkshire and Cheshire, and therefore the Derbyshire hills and the Yorkshire hills were out of the question. The only two districts from which water could be derived were the English lakes and the Welsh hills, without interfering with what might be considered in a national point of view the property of other districts. But the English lakes, at no greater elevation than the Welsh hills, were at twice the distance or nearly so. A direct line from London to the reservoirs in Wales is 167 miles. A straight line from London to Ulleswater is 212 miles, being a difference of 45 miles in a straight line. The distance to be traversed from London to the Welsh reservoirs is 183 miles; the distance to be traversed from London to Ulleswater would exceed 300 miles. It is 308 miles by a line I have sketched out, but it may be shortened about 19 miles by very heavy tunnelling, in a difficult part of the country, so that that would make it 289 miles, which may be called in round numbers about 300 miles. You therefore have a difference of 120 or 130 miles between the one scheme and the other; the elevation of the reservoirs in Wales and the elevation of Ulleswater being nearly the same, the discharge pipe of the Welsh reservoirs being 450 feet above Ordnance datum, and the level of Ulleswater being 476 feet above Ordnance datum, from which, if you deduct something like 16 feet, the depth to which you must draw the water from Ulleswater in order to make it a reservoir at all, it will give you 460 feet. Therefore, at 300 miles off you have a starting point of 460 feet, against a starting point of 450 feet at 183 miles off. The result is, that after allowing for the loss of fall which must accrue wherever you have to cross a river or a valley by syphon pipes, where you have to allow, in order to avoid expense, five feet of fall in a mile, you can in the one case get an available fall for your conduit of about an average of from 10 inches to a foot in a mile, delivering the water at 250 feet above Ordnance datum at your service reservoirs 10 miles from London; and in the other case, after allowing for syphons, you can only get an available fall for the whole of your conduit of about 7 inches in a mile, and consequently, to convey the same quantity of water, inasmuch as velocity and power of conveyance depend upon declivity, you must have a larger conduit from Ulleswater than you must have from Wales, the result being that in addition to the greater length you must have for the whole of the distance a more costly aqueduct to convey the water. I merely mention this matter because a consideration of all these circumstances (and I gave the whole subject full consideration) determined me in going to the Welsh hills. I saw that there you could get everything nearer, and at an elevation which would enable you to make the works cheaper than in any other part of the kingdom.

159. (*Sir J. Thwaites.*) What is the increase of capacity as between 10 inches and 7 inches?—A given conduit which from Wales would convey 300,000,000 gallons a day, would only convey 240,000,000 gallons from Ulleswater.

159*a*. (*Col. Harness.*) I observe that your reasoning is based entirely upon Ulleswater, and not upon the possibility of making artificial reservoirs in that district, as you propose in Wales?—You would not gain anything by artificial reservoirs because Ulleswater is a high lake. There is another lake higher still, namely Haweswater, and there are points where you can make artificial reservoirs. You must make your reservoirs at the bottoms of the valleys at elevations high enough, and you would get so high up the mountains in order to get a fall to London that you could not make the reservoirs in the valleys. Quite apart from that, the distance itself is so great that it would not be worth while to go there for the water. You cannot get reservoirs of sufficient capacity and commanding a sufficient area in the Lake district to give you the same inclination per mile.

160. You say that from your examination of the country?—From the physical condition of the country you cannot find valleys in the Lake district high enough to enable you to make reservoirs by which you could bring the water at the same inclination per mile, the distance being so much greater.

161. (*Sir J. Thwaites.*) It is not a question of distance, because you have the reservoirs already formed and at an equal elevation as that which you propose?—Yes, and at nearly twice the distance. I admit that there is plenty of water in the Lakes, and plenty of reservoir space, both that which is natural and that which may be constructed artificially; but then the distance for which the water has to be conveyed is in my opinion entirely prohibitory.

162. (*Col. Harness.*) The distance is half as far again?—The distance is as 170 to 310 in round numbers.

163. You have a working head of 200 feet?—We have not a working head.

164. You have a difference of level between your reservoir in Wales and the point at which you deliver in London of somewhere about 200 feet?—Yes.

165. If the distance is half as much again another 100 feet would make the position the same in the lakes as in Wales?—Yes.

166. What have you to say against that, because you have only reasoned upon Ulleswater?—There is no other lake which is high enough.

167. Is there no reservoir 100 feet higher than Ulleswater?—Yes, Haweswater would be higher; and you could make reservoirs higher, but I believe that you could not make reservoirs of sufficient capacity at the proper elevation.

168. You have not examined the matter with that view?—No; but I can very easily do it because the whole of that country is contoured, and we have the ordnance map, but knowing the whole district very well, having made large reservoirs there, I do not believe that it could be done; however, I do not mean to say that it cannot be done. My estimate for the cost of conveying the water is on the average 35,000*l*. a mile, and supposing that the works are no more difficult and no larger in going through the Lake district than in going through the Welsh district, but that you have about 130 miles more, you have

130 times 35,000*l.*, which will be 4,500,000*l.* or 5,000,000*l.*

169. How have you arrived at that 35,000*l.*; is it by comparison of what similar works have cost?—It is by my actual estimate of the work to be made.

170. (*Mr. Harrison.*) Upon what quantity of water is your 35,000*l.* per mile?—That is taking 220,000,000 gallons a day, but there would be very little difference in the cost, by a little change in the design, between making a conduit which would convey 220,000,000 gallons and one which would convey 300,000,000 gallons. At the end of the pamphlet before you you will find the designs for conveying 220,000,000 gallons a day with a fall of 14 inches in a mile in a covered conduit, and about the same quantity with a fall of 6 inches in a mile where it is open. Where you go through a perfectly open agricultural country you may make the conduit open; there is rather an advantage to the water than otherwise in its being exposed. Where you go through a populous district, or through a thickly wooded country, or upon the slopes of mountains where snow is liable to drift, and possibly to choke you, it is desirable to cover the conduit. Therefore I have assumed that half of the whole length should be covered and half of it open. This (*producing a drawing*) is a slight modification, and a very slight one, of the sketch which appears at the end of my pamphlet. Taking the open part first, that which is coloured pink, is the necessary work for conveying 220,000,000 gallons of water in 24 hours. The addition of these little purple bits, and the extra depth represented by the blue colour would enable that conduit to convey 300,000,000 gallons a day. In the covered portion, by adding 18 inches to the width of that which is shown in the sketch, and by giving a quicker invert a greater quantity of water can be conveyed. At 10 feet deep the conduit will convey 220,000,000 gallons or thereabouts, and by adding 2 feet in depth it will convey 300,000,000 gallons of water a day.

171. There are 6 inches fall to a mile in the one case, and 14 inches in the other?—Yes. With the fall which could be allowed from Ulleswater those conduits would convey up to the top of the blue line 240,000,000 gallons as against 300,000,000 gallons, taking Ulleswater as 460 feet, and the Welsh reservoirs as 450 feet, I get an available fall of 10 inches, taking the mean. From Ulleswater the available fall would be about $7\frac{1}{3}$ inches, which would give 10 inches for the covered part and about 5 inches for the open watercourse; and with those different declivities the same conduit would convey four-fifths of that quantity of water.

172. Is that assuming that the service reservoirs would be at the same height?—No; that is assuming that the service reservoirs from Ulleswater would be about 200 feet above the level of the sea, and the service reservoirs from the Welsh district 250 feet. Mr. Harrison will see that the strength of the work upon that section is very considerable, and that where we go through ground which is in itself water-tight, or is in itself hard enough, nothing like that quantity of work would be required. Those drawings are prepared for a difficult country, where the work requires being made water-tight, and very strong work to prevent injury.

173. This drawing does not show the depth of cutting necessary to arrive at that result?—No; but we are obliged to take an average, and I have taken 15 feet of cutting the whole way through, and upon that I have calculated the quantity of excavation. I put 2*s.* per cubic yard for the excavation at 15 feet deep.

174. Do you think that you could calculate exactly upon getting a line through that district with not more than an average of 15 feet cutting?—Yes; except where you tunnel, and then tunnelling is as cheap as anything else.

175. I suppose that in that case you take it from the top of the work?—Yes; you would generally have a little hillock over the covered part. Many times you would have not more than 10 feet, and sometimes 20 feet. I have allowed 60 cube yards of cutting on the average of the whole. For the covered aqueduct I have allowed $7\frac{1}{2}$ yards of brickwork at 20*s.* a cube yard. For ashlar skew-backs I have allowed 2*s.* a cube foot, concrete 10*s.* a cube yard, and excavating 2*s.* a cube yard. Then I have sundries. Then I have the land in addition, and I have 15 per cent. upon all this work. I allow 1,500*l.* a mile where the ground is covered for crossing drains or small streams, either under or over. Then in the open conduit I have the same prices for brickwork, and I have 3,000*l.* a mile for fencing, and for culverts over or under, and for bridges. Now all that I have to do in the bridges is to introduce a little bit of covered waterway instead of open, and the difference is only about 3*l.* a yard between the covered and the open waterway. Then I have a further sum of about 120,000*l.* for any difficult works which may occur, anything beyond what is covered by this estimate, which I consider a large one, because I have the experience of Glasgow, where I know pretty well what the average cutting was. Our general plan was to keep ourselves rather more than half in cutting, and about half filling over, so that we might have the lower half in the solid, and the material which we excavated would be heaped up over the work and form a waling as it were all along. We merely had to take care that the drainage of the country was not interfered with by that means. Therefore we got half the depth of our work, and there the material was heaped on to the top.

176. Will you give the length of tunnelling on your Glasgow works?—The length of tunnelling on our Glasgow works was 13 miles out of 27, the distance from Loch Katrine to the Mugdock reservoir; that is direct tunnelling.

177. What proportion was carried by pipes?—For 8 miles by road from the service reservoir to Glasgow there are two lines of pipe.

178. Of course the remainder will be open work?—There is no open work at Glasgow; the whole was tunnelling or cut and cover. Of the 26 miles which lie between Loch Katrine and the service reservoir 13 miles are tunnelling, $3\frac{3}{4}$ miles are iron piping, and the remainder, where the ground has been cut open, is an arched aqueduct of 8 feet in diameter, having the same inclination as the tunnels.

179. Can you give me the total cost?—The total cost of works, including reservoirs and piping in the city of Glasgow, and land and houses, and everything else so far as engineering cost went, was about 700,000*l.*, the distance being 35 miles. The total cost, everything included, was nearly 900,000*l.* The most costly tunnel which we made, including everything, was about 15*l.* a lineal yard, including the shafts. I believe the cost of the tunnel was about 12*l.* a yard; including the shafts and every expense it was about 15*l.* a yard.

180. (*Sir J. Thwaites.*) The 35,000*l.* a mile does not include the cost of the reservoirs?—No.

181. Neither in Wales nor in London?—No; that is the mere cost of the aqueduct itself, the construction of the work and the land which it will occupy; it does not include reservoirs in Wales nor the service reservoirs in London, nor the piping from the service reservoirs to join the other piping.

182. (*Mr. Harrison.*) As I understand you the total cost of the engineering works in the case of the Glasgow waterworks was about 700,000*l.*?—It was 712,000*l.*; that included the whole of the piping in the city of Glasgow.

183. Including the whole of the works the land and every contingent expense, it was 900,000*l.*?—I think that what I have stated did not include the land. The cost of the engineering works in the service reservoir at Mugdock, the aqueduct, and two lines of pipes to Glasgow was 712,000*l.*

184. What was the additional expense to make the total 900,000*l.*?—It was for land and parliamentary contests, and engineering superintendence, and interest on money during the construction of the works, and everything of that sort.

J. F. Bateman, Esq.

7 Feb. 1867.

185. Did you calculate that the actual distance occupied about 35 miles to Glasgow?—Yes, in round numbers.

186. That, everything included, was under the cost of 35,000*l.* a mile which you are now taking?—Yes, but the one is for 50.000,000 gallons, and the other for 220,000,000 gallons or more.

187. Do you recollect what you paid for the old works at Glasgow?—We purchased two waterworks, together I think they were between 500,000*l.* and 600,000*l.*

188. (*Chairman.*) That was for all the waterworks in Glasgow?—Yes.

189. (*Mr. Harrison.*) What is the rating in Glasgow?—The rates actually levied in Glasgow are 1*s.* in the pound on the rateable value for the domestic supply, and 1*d.* for the public rate; there are two rates, one a domestic rate for the supply of houses, which take the water for a domestic purpose; and in addition to that, upon those houses and upon all other property, with the exception of some modified charge for railways and other things, there is a rate of 1*d.* in the pound, which makes the total charge upon houses 1*s.* 1*d.*

190. What was the rate before the new works were introduced?—The rate was the same, or rather more, it was 1*s.* in the pound by the old companies, and it is only 1*s.* in the pound now. On page 20 of my pamphlet you will find the following statement: "Shortly "after the completion of the Loch Katrine works, "when the full amount of interest on capital came to "be paid, and before the expansion of the supply for "trading purposes had had time to develope, the "domestic rate in Glasgow rose to 1*s.* 4*d.* in the pound "on the north side of the river, which in addition to "the public rate was cheerfully and thankfully paid." It has fallen now to 1*s.* for the domestic rate, and a penny for the public rate. Then in Manchester the actual rates paid are 9*d.* in the pound for the domestic rate, and 3*d.* in the pound for the public rate.

191. (*Sir J. Thwaites.*) That is a compulsory rate?—It is a compulsory rate in both cases.

192. That is to say, that supposing rateable property does not receive the water, it is obliged to pay?—Yes, everybody is obliged to pay; they must have water, and if they do not take the water in the regular way they must steal it. All houses must pay the rate, it is compulsory upon everybody to pay the water rate.

193. Take a warehouse, for instance?—A warehouse must pay 1*d.* in the pound in Glasgow and 3*d.* in the pound in Manchester. If you take it in round numbers, some years ago the rateable value of property, both in Glasgow and in Manchester, was 1,200,000*l.* Of that sum, in both cases, about 600,000*l.* was the rateable value of dwelling houses, and upon the 600,000*l.* in Glasgow you levy 1*s.* in the pound, and in Manchester 9*d.* in the pound. Upon the 1,200,000*l.* in each case you levy a 1*d.* in the pound in Glasgow and 3*d.* in the pound in Manchester.

194. (*Mr. Harrison.*) Was it the fact that before these works were completed, and before the inhabitants were charged with any interest upon the works, they had to pay 1*s.* in the pound in Glasgow?—Yes.

195. And you have expended 900,000*l.* without their paying any more than they paid before?—Yes, except for the first two or three years after the works were introduced, and then the rate remained the same as before. They left a little deficit, and they rose the rate to 1*s.* 4*d.*, and they dropped it to 1*s.* 3*d.*, and then they dropped it down to 1*s.*, the same as it is now. Therefore the rate now is no more than it was before they expended in round numbers a million of money, and from this time it will become less.

196. (*Sir B. Phillips.*) I suppose that as the debt becomes liquidated the rate will decrease?—Yes, the liquidation is very slow, but in time the whole thing will be free, except the cost of maintenance.

197. (*Mr. Harrison.*) In this case you have generally based your estimate upon the experience which you obtained in the execution of your Glasgow waterworks?—At Glasgow and Manchester, and every other place.

198. (*Sir J. Thwaites.*) Can you tell us the rate of interest at which you raised your money in Glasgow?—I do not quite know that, but it was between four and five per cent.

199. They have no Government guarantee?—No; but there are compulsory rates upon the whole of the property in the city.

200. (*Sir B. Phillips.*) There is power I suppose under the Act of Parliament to raise the money and to levy a rate?—Yes; it is not only a compulsory rate, but as far as the domestic rate in Glasgow goes it is unlimited; it is limited to 2*d.* in the pound I think for what is called the property rate in Glasgow, and it is unlimited as far as the domestic rate is concerned. In Manchester both rates are unlimited as well as compulsory.

201. Do you mean by "unlimited" that there is no defined sum under the Act of Parliament?—Whatever money they want to pay the interest of the money borrowed, if it is 5*s.* in the pound, they have power to levy it, and the result is much to the advantage of the public, because the security is so good that they borrow their money at the lowest possible rate of interest, as a proof of which the whole debt of Manchester is now held at 4*l.* 0*s.* 10*d.* per cent.

202. (*Sir J. Thwaites.*) Do you know how they raised the money in Manchester?—By borrowing from anyone who would lend it.

203. By public tender or by private negotiation?—By private negotiation. They first borrowed a certain sum of money from the Exchequer Loan Commissioners, and they then found that they could borrow it in the open market at less interest, and they borrowed their money in the open market, and paid off the Exchequer Loan Commissioners, and they now borrow in the open market just as they find it convenient.

204. The interest being I suppose paid half-yearly?—I suppose so.

205. Is it by means of bonds or mortgage deeds?—By mortgage deeds. They also have what are called waterworks annuities. They agreed to give what they called an annuity for the purchase of the old Manchester and Salford waterworks in Manchester; it was not in the first instance an annuity, but they agreed to give so much a share by bonds carrying interest for the purchase of the old companies, and they purchased up these works by perpetual annuities of four per cent.

206. The first annuity was terminable?—Yes, in the sense of being purchasable at any time. Instead of continuing that they have turned it into perpetual annuities, and they give the parties four per cent.

207. I understand that the 35,000*l.* a mile includes 15 per cent. for extras?—15 per cent. for extras and for the land.

208. What part of the 35,000*l.* is for structural works?—The whole of it except the land.

209. There are extras which you have attached in your average of the cost per mile?—The whole sum in my estimate includes 15 per cent.

210. How much have you allowed for the purchase of land and severance, and injuriously affecting property?—About 840*l.* a mile.

211. That includes purchase and severance?—There is no severance where the work is covered, the land is all restored and given up again.

212. But there are places where the work is not covered?—Yes; and it includes the purchase and severance in those cases. Where the land is covered you purchase a wayleave, and restore the land to the owner on the condition that he does not build over it.

213. Have you taken into consideration the question of easement where you are in tunnel?—That price is the average, which includes the purchase of an easement on land in any case. A mere easement has been ordinarily purchased for about 100*l.* a mile. In Manchester we gave 100*l.* a mile for easement; in Glasgow we gave a great deal less than that; but in

Manchester wherever we occupied the land beneath the surface, restoring the surface, and restricting the owner from building over it, and allowing us to repair from time to time, we paid about 100*l.* a mile for that easement. Here I have 840*l.* on the average from one end to the other, much of the land being purely agricultural land, and much of it being worth very little. This map shows the line of conduit from the lakes.

214. (*Mr. Harrison.*) That may not be the course proposed by the promoters of that scheme?—No, but it must follow the contour of the country. I shall, however, be very happy that Mr. Hemans should describe it for himself. It is a singular thing that we so completely avoid all dangerous ground, and only just do so. The water will be conveyed in the manner which I have described, and by the sections which I have exhibited crossing the different valleys of the Severn and the Avon by syphon pipes which I propose to put down, namely, 4 feet cast-iron pipes. Pipes of the same size were put down in Glasgow with a fall of 5 feet in a mile wherever they occur, and putting them down from time to time as they may be required. I do not vary from the estimate which I have put in the appendix to my pamphlet; but as that only shows you first of all the cost for 130,000,000 gallons of water, I will give the gross cost for 220,000,000 gallons, and I can give you the gross cost for 300,000,000 gallons. For 220,000,000 gallons the summary of the cost would be as follows: at the reservoirs and works of collection upon the two branches, the green and the red district 1,080,287*l.*; the aqueducts from each of these districts to Marten Mere at the point of junction, taking the two together, would be 1,073,497*l.*

215. (*Mr. Prestwich.*) What is the length of those aqueducts?—19 miles and 21 respectively. The cost of the aqueduct from Marten Mere to London is 5,860,731*l.* The additional syphons on the main aqueduct, when required for 220,000,000 gallons of water, would cost 550,000*l.* For the service reservoirs near London I have allowed 500,000*l.*, which includes the cost of taking the water from there to a junction with the mains near Hyde Park, where you fall in with all the great mains of the various companies. Those figures make a total for 220,000,000 gallons a day of 9,064,515*l.*, that is exclusive of interest on money during the progress of the works, for which in the appendix you will find I have allowed 1,140,000*l.*, and it excludes the outlay for additional piping in the metropolitan districts when you come to use as much as 220,000,000 gallons, for which I have allowed in that appendix 600,000*l.*, making the total of my estimate in the appendix, which is in fact the same estimate as now for 220,000,000 gallons, 10,850,000*l.* including interest of borrowed money, and every other expense. The average cost of the aqueduct from the junction of the two branches to London, including the cost of syphons, is 38,000*l.* a mile, that includes everything. Dividing the 5,860,000*l.* by the distance it comes to 38,800*l.* a mile.

216. (*Sir B. Phillips.*) What is the distance?—151 miles, that is from Marten Mere to the service reservoirs at Stanmore for the aqueduct to convey the water. As to the 300,000,000 gallons of water, I can give you the additional cost of the aqueduct. Of course, inasmuch as I only estimate for the reservoirs which I have laid out, the district which I have appropriated will give you only 250,000,000 gallons, and therefore for 300,000,000 gallons you must go into an adjoining district, unless you have more water than I have assumed, and you make more reservoirs in the same district for the extra 50,000,000 gallons, which I have no doubt you can do. As the cost for each of these districts may be called in round numbers 500,000*l.* for about 125,000,000 gallons a day, an extra 50,000,000 gallons a day may be probably obtained for 250,000*l.* or 300,000*l.*, as the cost of storing and collecting in the district. Then the extra cost of conveying for the 151 miles will be about 4,000*l.* a mile, that is 600,000*l.* in round numbers, as the extra cost of the aqueduct for conveying the full quantity of 300,000,000 gallons, which is 80,000,000 gallons more than the former estimate. Then you have the further cost for enlarging the two branches, which I suppose would be 50,000*l.* The whole cost of procuring 300,000,000 gallons, including aqueducts, reservoirs, and all other cost, would be about a million sterling for getting an extra 80,000,000 gallons a day.

217. (*Mr. Harrison.*) Will you refer to the 1,100,000*l.* and state how much of that you calculate for reservoirs?—The reservoir at Llanwddyn, exclusive of land, is 54,256*l.*; the reservoir at Can-office is 45,546*l.*; the reservoir at Nant-e-Eira is 26,200*l.*; the reservoir at Rhyd-e-Gro is 77,193*l.*; then the reservoir on the Clywedog is 24,903*l.*; the reservoir on the Dulas is 25,000*l.*; the reservoir at Trefeglwys is 139,926*l.* Then 15 per cent. has to be added to all those figures. The total in the Bauw and Vyrnwy Valley is 538,000*l.*, and in the Severn Valley the total, including land, is 542,285*l.*; the land in the two cases comes to 325,000*l.*

218. Those figures amount to the 1,100,000*l.*?—Yes.

219. I do not see what portion of that sum is for the construction of the aqueduct?—You are now looking at the appendix.

220. Yes.—I am now giving it to you in a different shape. Looking at the appendix, you must add the 1,100,000*l.* in the one case, and the 1,100,000*l.* in the second branch together, which makes 2,200,000*l.*

221. Taking these minor aqueducts you have about 22,000*l.* a mile?—Yes, I should think about that.

222. You said that you would produce some sections?—This is a section assuming that at the same distance from London, whether you go to the lakes, or whether you go to Wales, up to that point the works in either direction are the same; and then it shows the difference of works from that point forwards, whether you go to the lakes, or whether you go to Wales. The lower section shows the character of the works up to the point at which we come to the reservoirs in Wales; and the upper section shows the character of the works according to the best line which I could lay out from near Stafford, (which corresponds with Bridgenorth in point of distance) to the lakes. This part, coloured pink, beginning at Bridgenorth, shows the line of works from there to the foot of the reservoir at Rhyd-e-Gro. (*The witness explained the section to the Commissioners.*) The section above shows the character of the country which must be passed through in getting to the lakes. The dark colour shows the coalfield; that is about the position where the line must cross the central ridge of the country if it comes down the Trent Valley, and east of the London and North-western Railway; from this central ridge northwards it goes through the new red sandstone till it comes to the Cheshire and Lancashire coalfield, and that is the general line which it must pursue until it gets to the final ridge at Kirkstone pass.

223. With regard to your own section, that is merely prepared from such data as you can get from the ordnance survey?—My part is not done from any marks upon the ordnance survey, except so far as the levelling goes, and from barometric observations over the hills.

224. But still for that you have certain data which are reliable?—Yes, it will be very nearly that. There are certain fixed points which we have, and the intermediate portion has been walked over with the aneroid barometer. This is the line which, according to my knowledge of the country, must be taken pretty nearly between one point and the other.

225. As I understand you, you do not propose to put in even an approximate section of the whole of your route?—I have not prepared one, but I will endeavour to do it if you wish me to do so.

226. To take an actual level from end to end where there are no contour lines on the ordnance surveys would cost probably several thousand pounds?—Yes,

J. F. Bateman, Esq.

7 Feb. 1867.

it would cost comparatively little in the hill district; but when you come into the swelling features of the centre of England, so much examination is required as to whether you should go up this valley or that valley, or take this or that direction, that it would be a troublesome matter to find out the very best line between there and Bridgenorth.

227. Might it not upon actual survey be found that the length of your line might be more than you have assumed?—It might be so, or it might be shorter. We have taken a line which according to our experience would be pretty nearly the line. I do not believe that it would vary much. We have certainly the district of country, and I believe that we have very nearly the line which should be taken. Of course I shall be very glad to have the whole thing taken, but what I have done has already cost me a good sum of money.

228. In a matter involving several millions of money, I think that hardly any engineer would give such an opinion as would decide such an important question as that of the cost, without having an accurate survey taken?—Not as to the precise cost.

229. Nor within a reasonable limit?—I believe that I can within a reasonable limit. I think that I know the cost of works of this sort so well, and that I have examined the country so sufficiently, as to be enabled to say that within a reasonable limit, say certainly within 20 per cent. above or below, I can give the actual cost of the work.

230. What do you say would be the cost of making the survey complete, would it be 10,000*l.*?—Yes, I think so, from 5,000*l.* to 10,000*l.* It would cost more than a railway, because in a railway you determine your line and accommodate it by inclination, but this work must be on such a uniform and gradual inclination as requires a considerable amount of examination.

231. (*Chairman.*) Can you give us what you estimate as the annual cost of the maintenance?—It would be so insignificant that I think it may be disregarded. The annual cost of the maintenance upon the Loch Katrine aqueduct is really nothing. It was my duty for some years after the works were completed to make periodical investigations, and they came to nothing more than pleasure excursions, and I could not reconcile it with my conscience to receive pay for pleasure excursions; there was absolutely nothing to do, no repairs were required, and after two or three years I gave it up, and gave it into the hands of the Commissioners.

232. (*Mr. Prestwich.*) But there you chiefly passed through very hard rocks?—We passed through the old red sandstone for about half the distance, which is very troublesome to deal with. I do not think that these works if properly constructed would cost any more to maintain, because it does not depend upon the strata themselves, but upon the actual construction of the work. There would of course be superintendence. I can hardly tell you what it would be. I have not gone into that question, but we should require one man at every reservoir; supposing that there are no repairs to do, one man would be quite sufficient, and then we should have a certain number of men stationed along the line of works for the purpose of inspection, and to see that everything was right, and to report how the thing was going on. The expense of that would not be very much. In Manchester we have about eight men at wages of about 30*s.* a week, and the same number in Glasgow.

233. (*Sir J. Thwaites.*) That is outside the area of distribution?—Yes. The Manchester waterworks are more troublesome to look after than the Glasgow waterworks. At Glasgow for a distance of 26 miles we have eight men; you would require about ten times that number. You would require from 70 to 80 men if the line of works was equally well manned, that is exclusive of superior supervision, which of course would have to be exercised.

234. (*Mr. Harrison.*) The whole of your open portion of work being lined with brickwork, do you think that it would be entirely free from all question of weeds growing in it?—Absolutely so.

235. And from any essential deposit?—There would be no deposit; there is no deposit at all in the Glasgow waterworks.

236. The Glasgow waterworks are covered from end to end?—Yes. When I say that there is no deposit, for a short time after the works were made there was a certain amount of sand which came in from the surface of the tunnel where it had been made in the new red sandstone. At the very top, perhaps from not having been made so tight as the rest, there was an infiltration of a very small quantity of sand; but if properly managed there would be no deposit whatever, the water would be delivered perfectly pure; it would run in a paved channel the whole way, and excepting a disintegration in the bricks or in the mortar which united them there would be nothing.

237. In process of time would not that disintegration probably take place?—No, not if your bricks and mortar were good. If the upper part were lined with a facing of Staffordshire blue bricks there would be absolutely no disintegration. The other part, which would be always under water, would require nothing but facing with good ordinary bricks.

238. (*Chairman.*) Have you any proposal to lay before the Commission as to how the money is to be raised to carry out this scheme?—That involves a large question. It involves the consideration of how you are to deal with the existing companies. My proposal is, I hope, pretty clearly explained in the pamphlet before your grace that the existing companies should be purchased. What I think ought to be the principle of water supply in London, as in all large cities, is that the waterworks and the distribution should be in the hands of the inhabitants themselves, and that they should be empowered to levy compulsory rates upon everybody occupying property within their limits of distribution, for the purpose of paying the interest on the requisite outlay and the cost of maintenance.

239. Would it be possible to carry out such a scheme as you devise, unless some such power as you have now sketched were given?—I hardly think that it would. At the same time I believe that it would be a very valuable undertaking if undertaken simply as a commercial transaction.

240. Upon the question of supply, and that this should be the only supply, as I gather from your evidence, has it ever occurred to you that there might be some danger in having so large a population as that of London and the suburbs solely dependent upon one supply of water, which yours would be. For instance, take the case of war, or take the case of a rebellion, or take any such extreme and improbable case, but though very improbable not wholly impossible, in which the supply of water might be interfered with or cut off, there would be 4,000,000 people without the means of having water?—I have considered that point. For ordinary cases of interruption I have provided by proposing reservoirs of so large a size near London, that within ten miles there would be storage to cover any possible contingency of interruption from accident or repairs required on the line of conduit, and by proposing that the works should be made in so permanent a manner that there would be no liability of their getting out of order; but as to the contingency of the water being cut off in the case of the country being occupied by a hostile army, I have no answer to give.

241. That never occurred to you as a possibility?—In that way you would have every city in Europe very much in the same position. Madrid is supplied with water from the mountains by a conduit of some 40 or 50 miles in length, and is solely dependent for its supply of water upon that conduit. Paris is now being supplied with water from a distance of 150 miles from the city, and although it may obtain some of its supplies from another source, yet the extension of the city, and virtually the safety of its supply of

water, will depend upon the maintenance of a conduit going out into the country 150 miles. I do not see how you can get over that. In Manchester, also, the conduit might be cut off and the supply interrupted, and in Glasgow the same.

242. Those are contingencies so remote that you have not considered them?—I think that they may be regarded as so remote that they may be well allowed not to weigh here. The quantity of water with which we are now dealing, namely, 300,000,000 gallons, is equal to the whole volume of the river Thames in extreme dry weather; and to pump out the whole volume of the river Thames, and to supply it to London, would be attended with so large an expense, that as compared with that it is worth while to incur the expense and the risk of this possible contingency, rather than to leave the city deprived of so valuable an addition to its comfort and its health as a supply of pure soft water.

243. (*Mr. Prestwich.*) For how many days would your service reservoir suffice?—For three weeks.

244. In case of long-continued frost what would be the effect on the supply of water to the reservoir?—Deep water scarcely ever freezes. Taking Loch Katrine, the winter of 1860-61, which was the first winter which occurred after the complete introduction of the water into the city of Glasgow, was a very severe winter; the temperature fell to 12 and 14 degrees below zero in the open air in the district along which the conduit was carried. But the temperature of the Loch Katrine water never fell lower than 39 degrees, namely, 7 degrees above freezing point, and there was not a particle of ice in any shallow or bay in Loch Katrine. After passing under cover, partly through tunnel and partly in a covered conduit to the Mugdock reservoir, 26 miles, the water acquired a temperature of 41 degrees, having gained two degrees in passing through the earth. So that where the water is principally carried underground, and where it is taken from deep reservoirs, the temperature would be such as to prevent freezing. If the water was wholly exposed in a shallow river, it would freeze, but with water ten or twelve feet deep, as would be the case here, and constantly going under cover, and being protected from excessive cold, I do not believe that it would freeze at all.

245. (*Sir J. Thwaites.*) There would be open cuttings?—I do not believe that the water would freeze there, because it would always be passing for half its length under cover.

246. And it would regain its temperature?—Yes.

247. (*Chairman.*) Have you made any calculation as to what amount of rate would be required?—Yes. That again involves the consideration of the payment to the existing companies; a rate of 10*d.* in the pound for domestic purposes, and of 2*d.* in the pound for public purposes, would pay the interest of the cost and dividend to the existing water companies at their present rate, or an equivalent, and the expense of management.

248. (*Sir J. Thwaites.*) The capital of the companies would be in addition to the 11,850,000*l.*?—Yes, subject to considerable deduction, because you would have a large amount of property which would then be found useless for the purposes of water supply, and which would be saleable, and you would save all the cost of pumping and eight separate managements.

249. (*Mr. Harrison.*) What is the present rate?—About the same.

250. (*Sir J. Thwaites.*) Would you save what you have stated as a matter of purchase?—If you became possessors of the present waterworks you would have a large amount of property which you could convert into money. For instance, a large portion of the income of many of the companies is derived from chief rents and not from water rents, and therefore that property would be saleable, it would not be part of the waterworks; and all the pumping engines and the very valuable land which in many cases they occupy would be saleable.

251. Assuming the capital of the companies to be 6,000,000*l.* or 7,000,000*l.* that must be added to the 11,850,000*l.*?—Yes, or its representative in interest.

252. That would make 18,000,000*l.* or 19,000,000*l.*?—It would,

253. And on that amount you assume what rate of interest?—Before coming to the net amount you must take the actual saving. If you capitalized the saving there would be a very considerable saving in the annual expenses of management, and so on, there would be the money derived from property and leases and useless machinery, and then you would have to pay the interest upon the money borrowed; and if you did not pay capital for the existing companies, you would have to pay either an arranged amount of interest or to secure them their dividends upon it, and to pay the expenses of management. That has all been very thoroughly and carefully gone into in the pamphlet before you.

254. (*Sir B. Phillips.*) Based upon the rateable value?—Yes.

255. (*Sir J. Thwaites.*) Would you permit individual shareholders of the old companies still to hold their property?—Yes.

256. And you would allow them to receive either a dividend or so much per cent. interest?—Exactly so. The shareholders in the Manchester waterworks had the offer of being paid a certain sum for their shares, or of receiving a bond for a perpetual annuity, and in the great majority of cases they preferred the perpetual annuity, which left them in the receipt of a fixed income, secured most amply upon unlimited compulsory rates on the whole property in Manchester, and those annuities are saleable in the market like any other stock and command a high price.

257. Supposing that you take the capital of the companies at 7,000,000*l.*, and that the holders of 5,000,000*l.* of that amount should elect to remain, you would have 2,000,000*l.* to add to your structural cost, bringing it up to 13,850,000*l.*, how do you propose to raise that money?—By borrowing in the open market, or by obtaining the money from Government.

258. (*Sir B. Phillips.*) In whom do you propose to vest the powers of construction?—That is a difficult point and requires a good deal of consideration, because there is no general board now in whom those powers could be vested, except that which is presided over very ably by Sir John Thwaites.

259. I understood you just now to say that the supply of water ought to be vested in the inhabitants themselves?—Yes, and at their cost and risk, and for their benefit. Of course the whole three millions of people could not have their finger in the pie, and therefore they would have to elect representatives in whom the undertaking should be vested.

260. In other words, Parliament would have to decide who should be the parties in whom it should be vested?—Yes. It would be equivalent to a municipal authority. In Leeds, and in Liverpool, and in Halifax, and in Manchester, and in a great many other places which I could name, the water supply is in the hands of the corporation, who have the power of levying compulsory rates within their own district, and of selling water like other trading companies to the outside districts which are not within their municipality. In Glasgow it is a water commission which is elected out of the corporation; the corporation is first elected in the ordinary way, and then out of the corporation is elected a body of commissioners, and they elect a water committee, and the water committee during their period of office are absolute masters of the waterworks.

261. (*Sir J. Thwaites.*) Do you think that there would be any difficulty in raising so large a sum of money, having regard to the period over which the works must necessarily be spread, probably eight or nine years?—No; I think that it is so much of an imperial question, that you might reasonably look in the first instance for aid, if it was required, from the

J. F. Bateman, Esq.

7 Feb. 1867.

Government, in exactly the same way as the Public Works Loan Commissioners afford assistance to many other undertakings. Their powers might be enlarged, and I think that in an undertaking which is of a national character you have a fair claim for assistance, if you find it necessary, just in the same way as there was an extension of the powers of the Public Works Loan Commissioners in the great calamity in the cotton district; but that need only be temporary, because I am sure that you would get the money lent to you by the capitalists of the country; nothing could be a better security if you adopted the principle of compulsory unlimited rates, which in my view is the right one.

262. (*Chairman.*) What is the rateable value of the property in London?—I am afraid that I cannot give you that quite accurately, and I think that Sir John Thwaites would perhaps have a better means of giving it than I should have.

263. (*Sir J. Thwaites.*) It is over 15,000,000*l.*—When I first took up this question some years ago it was 12,500,000*l.* and I did not then see my way to a satisfactory commercial result, and I dropped it. About 18 months ago I again considered it, and then I saw that the increase in the rateable value of property had been so great that it would be a profitable undertaking.

264. (*Chairman.*) You may take it that the rateable value of the property of the metropolis is now something over 15,000,000*l.*, or, in other words, that one penny will produce 62,000*l.*—Yes; therefore a shilling will produce about 720,000*l.*, a year, and you have in addition to that all the sale of water for trade purposes. But you must not take a shilling upon the whole of that; about two-thirds of it would be represented by dwelling houses, upon which 10*d.* would rest, and there would be 2*d.* upon the whole, and you would get a large income from the sale of water for other purposes. I estimated from the facts before me when I wrote that pamphlet, (and the estimate has been more than proved to be a correct one, by the increase in the value of property since that time,) that by the time when the works could be completed, and the water brought to London the rateable value would be from 18,000,000*l.* to 20,000,000*l.*, and I based the calculation as to the necessary amount of rate upon the assumed amount of 18,000,000*l.* at that time, of which 12,000,000*l.* would be upon dwelling houses, and 18,000,000*l.* upon all property.

265. (*Sir B. Phillips.*) The present rateable value of property produces something like 62,000*l.* a year at a penny in the pound?—Yes.

266. Why do you propose a rate of 10*d.* in the pound; 10*d.* in the pound would give 620,000*l.* a year?—Yes, but in round numbers you want 900,000*l.* to pay the interest upon the outlay, and the annuities, or dividends, or interest upon capital, which are represented by the existing companies and the management. In addition to the rate, you have water to sell for various purposes, and that is a very large amount indeed.

267. I do not think that we are charged here anything like 10*d.* in the pound for water.—You pay 1*s.* in the pound.

268; (*Sir J. Thwaites.*) And more than that in some places.—Yes, but it will average about 1*s.* in the pound. The increase of the population and of the rateable value of property in London is so rapid, that the rate to be paid by the inhabitants, as inhabitants individually, would not be greater than they pay for water now, although you expended 10,000,000*l.* in introducing the new supply. You would have the water of purer quality, and an unlimited supply at the same rate as you pay for your water now. We should have a water of superior quality, which by its softness would save an immense amount in other ways.

269. (*Mr. Harrison.*) What towns are there in the line of your aqueduct within reach, to which it would be desirable to supply water from this source?—There are no towns on the line which require water at all until we get into the midland districts, and then we get within 10 miles of the centre of a district which is probably the most difficult to supply of any large manufacturing or very populous district in England, namely, Wolverhampton, Dudley, Walsall, and Willenhall, and all the Staffordshire coal district, and Birmingham. They lie on the highest table-land in England, from which the water sheds in all directions. There are no hills near them from which they can obtain a supply of water, and I think that that district ought to be considered in any large scheme which would take the water near those places in its course. From Wolverhampton and from Birmingham the aqueduct would be about 10 miles distant. I am the engineer of the Wolverhampton waterworks. We pump water from the river Worth at Cosford Bridge, about 10 miles from Wolverhampton, and we raise it 400 feet. The line of aqueduct from the Welch district would be about 300 feet higher than the Worth at Cosford Bridge, where the water is now pumped from for Wolverhampton, and therefore there would be a saving of 300 feet, which is a very important thing. The intermediate district between Wolverhampton and Birmingham is supplied with water pumped from the new red sandstone at Lichfield, a distance of about eight or 10 miles. That is hard water. It is distributed by the Staffordshire Waterworks Company to a large and populous district. That water I think has to be raised about 300 feet. I know very little of the water supply of Birmingham, but I understand that it is in difficulty about its water supply, and I believe that its present supply by recent legislation is only granted to it for a limited period. I am not quite sure of that, but I think that it is the fact; Birmingham is certainly a town requiring a better supply of water, it being in a district which can hardly help itself. After that we do not pass any place which requires a supply.

270. (*Chairman.*) Should you be able to supply both Wolverhampton and Birmingham?—Yes, it is only a question of how much water they would abstract.

271. (*Sir J. Thwaites.*) You would have to increase the capacity of your tunnel?—A trifle down to that point. Of course it would be only reasonable that they should pay the additional cost of collecting and bringing the water to that point.

272. (*Chairman.*) Am I to understand you that you would have a sufficient supply of water to supply Birmingham and Wolverhampton and the metropolis?—There are 400,000,000 gallons of water a day available in the Welsh district. Birmingham, Wolverhampton, Walsall, Bilston, Dudley, Willenhall, Wednesbury, Stourbridge, and West Bromwich, which are all places where there is local difficulty in getting water, contain at present, according to the census of 1861, 522,000 inhabitants. They have supplies of water more or less. Wolverhampton has wells, and it is abundantly supplied with water. Walsall, Bilston, Dudley, Willenhall, and Wednesbury are all abundantly supplied with water from the sources which I have mentioned. I believe that Birmingham is indifferently supplied, and of Stourbridge and West Bromwich I do not know anything; but I can speak to 200,000 out of the 500,000 inhabitants being at present fully supplied with water. If they were left with their means of supply it would leave a population of 300,000, if all the supply of Birmingham was rejected, as the present population demanding a supply in that district. If you call it 500,000 persons, they would not require so much water per head as the London people would require. Giving them 20 gallons a head a day, which would probably be about their consumption (at Wolverhampton it does not amount to 20 gallons, I know the actual quantity there), it would be 10,000,000 gallons, and 10,000,000 gallons out of our large stock would not be very much.

273. Are there any other towns in the district nearer to the reservoirs?—Bridgnorth is the only place, except Montgomery, which is a small place. I do not know what its supply of water is, but it is close to the hills, and they could get it down very easily. I do not know the supply of Bridgnorth, it is upon the new red

sandstone, and close to the coal measures. Its population is perhaps about 5,000 or 6,000 and they would not require much water. From there to London there is no place of very great importance excepting Warwick and Leamington; you do not go far from those two places, and it might be that they might have a demand upon you.

274. (*Mr. Prestwich.*) You pass at no great distance from Coventry?—No, and Coventry I think is a place which might reasonably demand a supply. I believe that it is abundantly supplied now, and it gets it from the new red sandstone. I do not know much about that supply, it is in Mr. Hawksley's hands.

275. (*Mr. Harrison.*) Is Oxford at all within reach?—No, Oxford is too far off. Oxford is a town which is not well supplied, and cannot be well supplied with water, except by taking it from the Thames; it does not take it from the Thames now, it takes it from water collected in a gravel pit which was excavated by the Great Western Railway Company when they made their railway. The water collects from the hills in this gravel pit, and is supplied from there. It is not bad water, excepting that it is hard.

276. (*Chairman.*) You are aware that there are other districts from which it is proposed to supply London; there is the Lake district?—The lake district I have very slightly referred to, and there is the Derbyshire district, which will be laid before you. I have avoided referring to those districts except to bring out my particular scheme. Perhaps I may ask to be permitted, in case of any necessity arising, to answer or to observe upon any scheme which may be proposed, as I invite anybody to do who is desirous of saying anything in criticism upon the scheme which I have laid before your grace. I think that it is only fair that any objection which can be raised to my scheme by anybody should be raised, and that I shall have an opportunity of examining it afterwards, and perhaps in like manner I may be permitted, if need be, to observe upon any other scheme.

277. We now come to the manufacturing districts. Will you show us the ordnance map giving the waterworks and gathering grounds of some of the large towns? (*The witness produced the same.*)—It is not quite so fully prepared as I should wish it to be. The manufacturing district may be said to commence with Preston in the north. The collecting ground of Preston I have not yet marked. Then there are various other places, and there is also Liverpool. I propose upon this map to show you all the gathering grounds. I am either engineer for, or am connected with, most of the waterworks. The map is not fully prepared, but I can tell you the population of all the large towns and the condition of their present supply, and their means of giving it. As far as I can I will mark the extent of gathering ground to each district, so that you will be able to see how much of the district is occupied, and how far it can help itself. Manchester contains, including the population which it supplies with water, in round numbers, 600,000 persons. It gives a supply of 12,000,000 gallons of water a day, and it has a supply of 25,000,000 gallons a day, therefore that place is fully supplied. Stockport has a population of 70,000 persons, for which there is an abundant supply, partly by taking water, by arrangement, from the Manchester waterworks, and partly by gathering grounds on which a portion of the works authorized are constructed, with power to construct further works not yet constructed, because the water is not yet required, and therefore it wants no additional supply. Bolton has a population of 85,000 persons, it was formerly well supplied. I have executed some of the works for Bolton, and was for a long time their engineer, but it fell short of water three or four years ago, and two sessions ago I think we got an Act for a very considerable extension of water for the supply of Bolton from the hill district, which will give them, and all dependent upon them, a full supply for many years to come. I was also the engineer of the Accrington waterworks. Accrington has a full supply; I cannot now give you the quantity, but only five or six years ago new works were constructed there. Blackburn has been rather short of water, in consequence of works which were authorized six or seven years ago not having been so quickly carried out as they ought to have been. I am engineer of the Blackburn waterworks, and we are now executing works for a complete supply of Blackburn and its district. Preston has not long ago constructed waterworks from Longridge Fell by which it has an abundant supply of water, and it is close to a water-producing district from which it can get any sufficient quantity. Over Darwen, for the waterworks of which I was engineer, has an abundant supply of water, and the quantity from the gathering grounds is only partly occupied. Ashton-under-Lyne, with a population of 90,000 persons, is now constructing works for the supply of that town and of Stalybridge and Dukinfield, in a valley which has often been a point of contest with water companies adjoining the Manchester waterworks district, from which an abundant supply of excellent water can be obtained. Fleetwood, with Blackpool, Kirkham, and Lytham, has just constructed waterworks from which it gets an abundant supply. Heywood is a manufacturing place between Bolton and Bury and Rochdale, which some years ago got an Act of Parliament and works have been constructed by which I believe it gets a sufficient supply of water. Mr. Cawley is the engineer of those works. Wigan is I believe indifferently supplied; it is upon the richest part of the Lancashire coalfield, and it gets only a so-so supply of water from a questionable district. That is a place which may require an additional supply. I am the consulting engineer of the Oldham waterworks. Oldham is now about completing works which have been in course of construction from some years, by which it will get an abundant supply of water. At Warrington I constructed waterworks. They have I believe pretty well exhausted their supply, and may require an additional supply. I also constructed the early waterworks of St. Helen's. They have extended their works, and I am not quite sure whether they do not get a supply of water from the Liverpool waterworks by a conduit-pipe which passes close by. They may, however, require an additional supply. There is an adjoining place, namely, Widness, on the Mersey, near Runcorn, which is a very populous place. It is a chemical manufacturing district, and there I am advising them to seek for a supply of water in the new red sandstone, and they will get an abundant supply of water. St. Helen's also lies partly upon the new red sandstone, from which it can get a supply of water. Rochdale was in Parliament last year for extensions, and I believe it will get an abundant supply. Bacup lies quite in the hills, from which an abundant supply can be obtained, and I believe that it will not require any additional supply. Burnley has been recently constructing waterworks, not on a very large scale, but they are in a district close to the hills, from which almost any extension may be obtained. Bury has constructed very considerable waterworks from time to time, and has I believe an abundant supply; at all events it is capable of very large extension. Liverpool, which has a population of some 500,000 persons, is taking a considerable quantity of water, and it gets a portion of it from wells in the new red sandstone that is about one-third of its supply, it gets two-thirds of its supply from the hills in the district known as Rivington Pike. They for the last two or three years have been short of water, and they are now proposing to go, at all events it has been proposed and debated, and probably will result in their going to Bala Lake for a supply of water to Liverpool. They consume very much more water in proportion to the population than any other town in that district, and they are short, and they are prepared to expend a considerable sum of money in going to Bala Lake.

278. (*Col. Harness.*) Has Rivington Pike given them less water than was expected?—Yes. The estimate of Mr. Hawksley, who was the engineer, was 15,000,000 gallons a day. My estimate was

J. F. Bateman, Esq.
7 Feb. 1867.

J. F. Bateman, Esq.

7 Feb. 1867.

12,000,000 gallons if they had storage enough, but unfortunately they had not storage enough, and during a portion of last year and during two preceding years the quantity fell to about 11,000,000, 10,000,000, and under 8,000,000 I believe in the last year, but that was principally for want of storage. Last year they were in Parliament again for the purpose of creating additional storage, and for purchasing the water of a stream called the river Roddlesworth.

279. Do you know what storage capacity they have?—About 400,000,000 cubic feet altogether, and they have a drainage ground of 9,000 acres. Of Clitheroe, which is a small town of 10,000 inhabitants, I do not know anything at all; it is close to the hills. Colne with 6,000 persons is in the same position. Middleton, with a population of about 10,000 persons, is I believe dependent for its supply of water on Oldham. Haslingden, a very flourishing place in the centre of a large manufacturing district, in the valley of the Irwell, has waterworks recently constructed; and the people there have in their opinion so much surplus water that they propose to take it a long way into the country to those places which have not a supply. Leigh and Tyldesley are I think within the limits of the recent Bolton Act, but those are places which have been proposed to be supplied by the Haslingden waterworks. They are a good deal mixed up with the property of Lord Ellesmere, and there was a proposal not long since, which came before me as his lordship's engineering adviser, with reference to the supply of that district. Ormskirk, which is away from the manufacturing district, but still in Lancashire, is supplied by pumping out of the new red sandstone by works constructed by Mr. Rawlinson. Padiham is a small place close to the hills. Lancaster, with 16,000 persons, has its supply of water from the hills above. Southport has a supply of its own from the new red sandstone. Ulverston is in the mining and lake district quite away. That I think gives pretty nearly a list of all the manufacturing places north of the Mersey. In all these waterworks, with few exceptions, those exceptions being I think Stockport and Liverpool partially, water has been given as compensation for the abstraction of water. In that way the streams for manufacturing purposes have been increased, the value has also been increased, and the prosperity of the country as a manufacturing country depending upon power, so far as water power is serviceable for those purposes, has been enhanced. I have always contended, particularly in manufacturing districts, that that is the right principle, in a national point of view, upon which to pay compensation, for if, as at Liverpool last year, you grant powers to abstract the whole water of a river not being now employed for manufacturing purposes, and therefore not now contributing to the industry of the country, you absolutely deprive it of all future chance of being used for those purposes, you destroy the value of that property, and destroy the working power of the country, whereas, if the floods are impounded and partially delivered, so as to increase the working volume of the stream, you increase that working power. Indeed I think that it was altogether wrong that Liverpool should have been allowed to go to this district, because Darwen, Accrington, Blackburn, Wigan, and many other places are large and flourishing towns, closely contiguous to the Liverpool gathering grounds, the whole district having a dense population where the inhabitants can only look to this little cluster of hills for a supply of water. Liverpool has put its paw upon that supply and has very considerably limited the power of the surrounding districts getting an additional supply of water; and I would venture to suggest, as it is a national question, that if Liverpool should be permitted to go to Bala Lake for water, where it may take water without injury to any manufacturing interest, those hills being as it were the great manufacturers of water, the Rivington district should be held liable to have water abstracted from it for the supply of any neighbouring town which could not otherwise get a supply of water. I will give you this in greater detail, but I show you as nearly as I can give it to you the general position of the manufacturing towns.

280. (*Chairman.*) Will you be kind enough to supply us with reductions of the maps upon the walls which can be appended to our report?—I will endeavour to do so.

281. Can you also favour us with a section of your line from Loch Katrine to Glasgow?—Certainly.

282. Have you considered the effect which your scheme would have upon the navigation of the Severn?—The Severn I think is not navigable beyond Tewkesbury. There is a lock at Tewkesbury, and the last weir upon the river is at Tewkesbury; how far it goes above that I am not aware, but so far as the river is above the tideway any effect whatever would be beneficial, because while it diminished the floods to a very limited extent it would increase the dry-weather volume of the river.

283. Below that point you get into the tideway?—Yes; and I must tell you frankly that that is the only point on which I think it possible that parties may oppose this scheme with a show of reason, namely, those who may think themselves damaged by reason of the destruction of the present small amount of scouring power which would result from the diminution of the floods. The Severn is a river with an enormous amount of tidal water flowing both up and down, and any diminution of its scouring power derived from the hills will not be much; but it is right to say that there may be some mischief arising from that cause in the view of some parties, and as far as I can see that is the only point upon which any people can raise a reasonable show of opposition.

284. Your point is that the diminution of the scouring power would be so small that it would not be appreciable?—That is my opinion. When we proposed to take water from the river Forth and to turn it into the Clyde, we were opposed by the people interested in the Forth on that very ground, and we had lawyers' speeches (I do not know whether we had actual evidence) that St. Margaret's Hope, where the water is 60 feet deep, was in danger of being ruined. I had tide gauges and calculations made, and I showed how small any abstraction would be in proportion to the volume of water flowing up and down, and I satisfied the Committee that no mischief would be done, and there has certainly been no mischief yet.

285. You can speak with great confidence, from the experience of the Forth, that there would be no damage done to the Severn?—I do not believe that there would be any damage done to the Severn; above the tideway it would be improved.

286. Supposing that your scheme was carried out, how long would it take before it was completed?—Supposing that authority were now given for its execution it would be quite impossible to prepare working drawings and specifications for the commencement of the work in less than twelve months, and then with very great exertion, if there was no difficulty about money, and by proper arrangements, I think that it would be possible to execute the work in perhaps four years; but I think that it would be safer to assume that the shortest period within which the work might reasonably be calculated to be finished would be five years, that would be six years from the authorization to the introduction of the water. I may mention that in the case of the Glasgow waterworks, which occupied as long a time as these works would be likely to occupy, except that these are on so much larger a scale that they would be rather more difficult to handle, the time occupied from obtaining the Act was from early in the summer of 1855 to the early portion of the year 1860; about five years, or a little short of five years.

The witness withdrew.

Adjourned to Wednesday next at half-past 11 o'clock.

Wednesday, 13th February 1867.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND IN THE CHAIR.

Sir JOHN THWAITES.
Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.
THOMAS ELLIOTT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

GEORGE WILLOUGHBY HEMANS, Esq., examined.

G. W. Hemans Esq.
13 Feb. 1867.

287. (*Chairman.*) You are a civil engineer, and a member of the council of the Institute of Civil Engineers?—Yes.

288. Have you considered the best mode of obtaining water in the high districts of England and Wales with a view to supply the metropolis?—Yes.

289. And also to supplying other towns, and the intervening population?—Yes.

290. Mr. Richard Hassard, also a civil engineer, joined you in those schemes?—Yes, he has.

291. Which schemes he originally suggested to you, did he not?—Yes.

292. Since that have you conjointly with Mr. Hassard considered which would be the best mode of supplying water?—We have considered and worked up the scheme which is now before the Commission.

293. Have you any means of telling us from official documents the quantity of water which is used in London?—Yes.

294. With regard to the quantity of water which is used in London, is it a fact, taking it generally, that London at the present time consumes about 100,000,000 gallons per diem?—That quantity is accepted by all parties, I believe, as being the authentic quantity which is consumed in London.

295. And is it your opinion that London will in the course of a short time require that quantity to be very much increased?—We assume that at the present rate of progress London will increase 50 per cent. in the next 20 years, which would bring the population up to 4,500,000 instead of the 3,000,000 that there are at present, and it is believed and I believe that water is at present very inefficiently given, especially to the poorer inhabitants of London.

296. Are you of opinion that in the course of a short time the supply to London will require to be doubled?—At least doubled; in fact I may say that instead of 100,000,000 gallons it will require eventually 300,000,000 gallons; but I must add that I consider that provision ought to be made for 250,000,000 gallons at least.

297. Having stated that the present quantity is 100,000,000 gallons, and that in all probability it will require to be doubled, have you fixed in your own mind any period within which that supply ought to be so increased?—I think that by the time any great works could be completed so as to bring water either from the Welsh mountains, or from the Cumberland lakes, the necessity would arise for a very large proportion of this increased supply.

298. May we take it generally that you are of opinion that within the next 10 years it will be necessary to have the supply of water doubled?—I would hardly perhaps go so far as to say that a full double supply would be necessary within 10 years, but I am certain that more than half of that additional 100,000,000 gallons will be required in 10 years.

299. Assuming that you require to increase this supply, and that you propose to bring it from the higher districts of the country, how would you propose to do so?—Before I answer that question, would your Grace allow me to add something to my last reply, in which I said that in 10 years perhaps it might not be necessary to have the whole of the additional 100,000,000 gallons. I know this, that if it be true that the Board of Works will require some 42,000,000 gallons a day for the mere purpose of flushing the sewers, which has been publicly stated, then I think that the whole of the additional 100,000,000 gallons ought to be provided by the end of 10 years from the present time, if that large demand be necessary.

300. Having given that explanation, how would you propose to bring this very large quantity of water to London; will you tell us from what part of the high district you would propose to bring it?—The locality fixed upon by Mr. Hassard and myself is that of the Cumberland lakes, which possesses the only authentic record of a rainfall sufficiently large for the purpose, and which, although 270 miles from London, and not 310 as Mr. Bateman made it by the route that he took, may be said to be ready, to a certain extent, for the storage of water. The three lakes which we propose to deal with, consisting of Haweswater, Thirlmere, and Ulleswater, may be looked upon as natural reservoirs of water, in contradistinction to the numerous artificial lakes which Mr. Bateman proposes to make, and I trust that at this point we may express a hope that the Commission will visit both the localities, because it is a great part of our plan that we believe the surface from which water will be gathered, and which now pours into those lakes, is a great deal cleaner and freer from impurity than the surface of the Welsh gathering ground; we believe that those natural lakes of water are better suited to deliver water to towns than the artificial reservoirs which will be made over a cultivated district, now occupied by villages, churches, graveyards, and farms of considerable value; and we also believe that the water on the Welsh hills, in comparison to this which we propose, will be turbid, and that it will require filtration. The rivers have been visited, and Mr. Hassard, who will follow me in evidence, will prove that the water that he saw in the Welsh district was turbid, and would require filtration in coming to London. I mention all this at starting, before describing the method of dealing with the lakes in Cumberland, because we are very anxious that those distinctions should be impressed upon the Commission, it being obviously almost foolish to suggest a plan requiring 270 miles to bring water to London if an equally good one can be found within 183 miles, and having besides the very great scientific position of Mr. Bateman to contend with in this matter, who really has a reputation as a water engineer which neither Mr. Hassard nor I possess, we are very anxious to impress these salient points upon the Commission, and we hope that they will themselves view the grounds. I will now, with the permission of the Commission, proceed to refer to the map on the wall, and describe the mode of dealing with those lakes.

301. Before you refer to the map, let me ask you would you require, in order to bring this water to London, to create artificially a pure water river of 30 feet wide and 10 feet deep?—It would be necessary to have an artificial conduit consisting alternately of tunnels, open cuttings, and pipes equal to those dimensions, in fact a river of not less than 30 feet wide and 10 feet deep in round numbers, flowing at the rate of about a mile and a quarter per hour.

302. (*Mr. Harrison.*) What would be the inclination per mile?—The inclinations will vary. Taking the whole distance, we could give very nearly the inclinations which Mr. Bateman gave, which were, I

G. W. Hemans, Esq.

13 Feb. 1867.

think, 14 inches per mile, and six inches according to circumstances; but we have chosen smaller inclinations, believing that the safety of the aqueduct is greater with a small current than with a rapid current, and we adopt inclinations of six inches, and in some cases four inches, and for pipes a fall of from one foot eight inches to two feet, where pipes are used, in the form of syphons.

303. Do you not propose in all cases to line your conduit?—The conduit will be almost always lined, but not always so expensively, we think it not necessary to line it quite so expensively as in Mr. Bateman's project. He adopts a brick dish or conduit, I think, the whole way. We do not think that that is necessary. We know that the New River and many other conduits, and Mr. Bateman's own conduit, I think, to Glasgow, is not lined in that expensive way with brickwork, and we think that it rather tells (although I do not wish to insinuate that Mr. Bateman put it in that way) against our project, where the mileage is high, to put the expense on the culvert and leave it less at the lakes. We have no doubt that our conduit will be sufficient. We can exhibit the drawings of every section of it either now or later, but I propose leaving those details to Mr. Hassard, who has worked them up a great deal, and merely to give the chief points myself.

304. (*Chairman.*) It would nesessarily require, would it not, a very large rainfall, and storage in vast reservoirs, to keep up this river which you have now described during the dry seasons of the year?—Yes. In wet weather this river will be kept up by the rain that falls in the district, but in dry weather it is quite clear that the water must be heaped up in the mountains to supply the river, and that storage is what we possess in those lakes which I am about to describe.

305. Those lakes must be high enough for the water to gravitate to London?—Yes, they will be high enough to command the highest houses; 220 feet is the height that we obtain near London, at the high ground near Edgware.

306. Before you go into the details of the scheme, will you have the goodness to state what your view is as to the description of ground which is best adapted for forming the collecting ground?—I think all water engineers are agreed that the gathering ground which is to supply pure water ought to be as clean as possible; that it ought to be of that rock which gives soft water, and not, as the limestones do, water with a considerable degree of hardness. What the Silurian slates, which the Cumberland lakes are in, possess is soft water, an analysis of which will be laid before the Commission by Professor Way; and we find that the mountains round those lakes are particularly clean and rocky, that there is little or no cultivation, and that their height is such that there is never likely to be cultivation upon them. Our gathering ground is, on the whole, some hundreds of feet higher than the average of the proposed gathering ground in the Welsh mountains, and that is one reason which will always prevent cultivation from injuring the water which falls upon it, and therefore the supply will always continue to be clean and pure.

307. Would the water which you propose to supply, in your opinion, require any filtration?—We are convinced that no filtration whatever will be necessary with these waters from the lakes, whereas we think it will be necessary with the Welsh waters.

308. (*Mr. Prestwich.*) Does not the water come from the peat?—There is very little peat in the lake district.

309. (*Chairman.*) Have you a record of the rainfall in the lake district?—A record of the rainfall in the lake district was kept by Dr. Miller, who is now dead, but who kept the gauges for a great number of years, and the results have been recorded in various philosophical transactions. Since his death other observations have been made, and the gauges have been kept up, and are still going on to a great extent in those mountains. We are prepared to prove through Professor Symons, who has made it his business to publish works on meteorology, and to study especially the mountains, that the rainfall may be taken on the mean as 77 inches throughout our districts, that the minimum is over 60 inches, and that the longest drought on record during 44 years has been under 70 days.

310. Do you think that you could supply with water any of the places on the road between the lakes and London?—We believe that a number of towns on the road between the lakes and London could be supplied by this river of 30 feet by 10, including Liverpool.

311. What amount of water could you supply, or should you propose to supply by your scheme, to the places on the road, including Liverpool?—There would be no difficulty in getting from that district 300,000,000 gallons per day by extending the works, although we have only contemplated, at the present moment, 50,000,000 gallons in addition to the London supply at 200,000,000 gallons.

312. But how should you propose to devote that 50,000,000 gallons?—We have not made any apportionment, and it would require more time to ascertain what quantity each town might require or agree to take, but 50,000,000 gallons in round numbers is assumed to be ready for that purpose, and 200,000,000 gallons to go on to London.

313. (*Sir B. Phillips.*) Is 250,000,000 gallons supposed to be the total supply?—No, we are able to get from that district 300,000,000 gallons, but passing, as our conduit will do, close to the source of the Liverpool water supply, which is Rivington Pike, if it should happen that the Liverpool people would take the water from us, we being close to them, then instead of Bala Lake being taken to Liverpool it might be thrown into the London channel to make up for the quantity which was given to Liverpool.

314. (*Chairman.*) How is Liverpool at present supplied?—From a place called Rivington Pike, which I think is some 15 or 20 miles from Liverpool, from the Sandstones to the north, in a direction which we cross with our conduit.

315. Do you think that you can supply better water and at a cheaper rate to Liverpool than by going to Bala Lake?—Yes, I think so.

316. Is it the intention of the corporation of Liverpool to go to Bala Lake for the purpose of getting more water?—They have come to no resolution as yet, but it has been suggested to them by Mr. Rawlinson and other engineers.

317. (*Sir B. Phillips.*) You started by stating that the present supply to London was something like 100,000,000 gallons per diem, and supposing that the Board of Works required 46,000,000 gallons for the purpose of flushing the sewers, the 200,000,000 gallons would really be wanted for London within a given time?—Yes, within 10 years certainly, that is the quantity which will be required.

318. When we speak of the quantity of 250,000,000 gallons only, taking into consideration the growing wants of London, and putting your estimate as low as 200,000,000 gallons, do you think that it would be desirable to interfere with any portion of that 250,000,000 gallons which you propose to bring to London for the purpose of supplying any other city?—I will show the Commission presently, when I describe the lakes, that we could take 300,000,000 gallons altogether from that district alone without considering Bala Lake, and that if a conduit were made in the first instance big enough, 300,000,000 gallons could be taken to London, and part of that could be sold on the way instead of taking only 250,000,000 gallons and spreading part of that on the way. There are four districts which we contemplate using, as I shall show when I describe the lakes, of which only three are proposed to be taken now, and the fourth when it may be required.

319. (*Chairman.*) What would be the extent in square miles of the gathering ground which you pro-

pose to take?—177 square miles in the present project.

320. Is there any means of calculating with any degree of certainty what amount of rainfall would be necessary over that area to supply 250,000,000 gallons per day?—That has been calculated, and the quantity is less than one-tenth of an inch per day over the whole surface. I have put it at one-tenth of an inch for the sake of round numbers, but it is in reality a decimal less than that; one-tenth of an inch over 365 days would give, of course, 36½ inches in the year, and if we take for evaporation and absorption 12 inches more, which is the usual quantity to take, 48½ inches would be required to give us the 250,000,000 gallons. Beyond this a certain quantity would be required for compensation, and as we are able to prove, a rainfall of 77 inches, the difference between 48½ and that would go to compensation, that is to say, 28½ inches would go to compensation to supply the rivers that we take the water from. And that is a very large quantity indeed, for as Mr. Bateman stated the compensation need not be taken at more than one-fourth, and this would be considerably more.

321. (*Mr. Harrison.*) Your minimum rainfall is 60 inches, is it not?—I think it is 61 or 62 inches, but Professor Symons will give that exactly; however, it is over 60 inches, so that when the rainfall was at the minimum the compensation would be less, but still ample for that district.

322. (*Mr. Prestwich.*) Do you reckon upon having all the 77 inches of rainfall available with the exception of 12 inches?—No, we take 36½ inches.

323. You allow 12 inches to be lost?—Yes.

324. Then you reckon 28½ inches, do you not, for compensation?—That is the difference between the loss of what we take and the rainfall of 77 inches, assuming the rainfall to be 77 inches.

325. Then you consider that the 28½ inches are available, and the 48½ inches, with the exception of 12 inches which would be lost in evaporation and absorption?—Yes.

326. That is to say, you consider the whole of the rainfall available with the exception of 12 inches?—Yes.

327. Do you consider 12 inches enough to be allowed for evaporation in so large a fall as that?—The more rocky and bare a mountain is the less absorption there is, and probably less evaporation, because the water will all run down so quickly in a rocky district like that that there would be less evaporation than in a cultivated district, but it will be observed that there is an ample margin to spare even if we allow a larger evaporation. There is a very large margin, because 28 inches is a very large amount of compensation, and part of that might go.

328. The absorption would be very small in that district, it being very rocky, but what mode have you of arriving at a conclusion as to the evaporation?—From experiments upon evaporation. There are not many good experiments on the subject, but it is quite clear that the steeper and more rocky a district is the sooner the water runs to the reservoir, and the less time it has to evaporate on the way.

329. Have you gauged any of the streams in the district?—No, we have not gauged the streams, but we have measured the capacity of the lakes and the reservoirs and the rainfall, and it does not seem necessary to gauge the rivers with these data. If you have the absolute amount of rainfall and the acknowledged storage to hold it in the gauging of the rivers does not seem to be absolutely necessary.

330. (*Sir J. Thwaites.*) How do you arrive at the net result except by gauging the rivers?—We know the number of square miles upon which a certain quantity of rain falls; we know the capacity of the only place where this rain can go; and we know what is usually considered the proper allowance for evaporation and absorption.

331. But how do you arrive at the conclusion that 12 inches is the proper amount to allow for evaporation, seeing that you have 4,000 acres of surface exposed, from which there will be an evaporation of probably six or seven inches?—With regard to that I can only say that a great number of experiments and gaugings have been made in a number of districts, and that if you take the worst districts, like those districts in which the water lingers, as it does in bogs, where it is held by the spongy nature of the soil, and where a great amount of evaporation goes on, and gauge what comes off, and find the maximum and the minimum; and if you take the very best district for evaporation, for instance the roof of a house, where there is no evaporation, because when the rain falls it runs away and gets into cisterns at once; and if you strike a mean between those two, that mean will amount to 12 or 14 inches. Those are the data which we go upon, and which are generally accepted.

332. It comes to this, does it not, that you have a lake of a given area, which you call your storing power, and you have a given amount of rainfall and a given amount of absorption and evaporation?—Yes.

333. The best practical proof of the correctness of the amount of absorption and evaporation would appear to be to test the quantity at the point of discharge of the lake, because you would get the net result; but the question which my colleague put to you was this, whether you have gauged the outfall of those lakes so as to ascertain the daily discharge from them, and whether that daily discharge was equal to the amount which you calculate will be required from the 48 inches which you have at your command?—I entirely concur with what is stated in the question, namely, that if you want to ascertain absolutely the evaporation or loss in any given district, the best test is by gauging the water that flows off it; but it must be remembered that here there is a very large excess of rainfall, and if you have 28 inches, as is supposed, or anything like it to run off, there is no necessity for that extreme nicety in the first instance in an inquiry like this. There is no doubt that those great rivers which are rapid streams and liable to great floods might be gauged, but it would be a very tedious and costly work, rather too much to expect in the initiation of a project like this, especially when we feel that there is such a margin of water, and that no important result depends upon that point.

334. Have you walked over the ground yourself?—Yes.

335. Have you examined carefully Haweswater, which is the highest elevation?—Yes.

336. Did you examine the discharge at the lower end of the lake?—Yes.

337. Did it not occur to you that it was exceedingly small compared with the gathering ground?—The discharge varies considerably. It will be small in dry weather, and full in wet weather. But I was about to explain that an immense amount of water that does not run through now will be brought to Haweswater; the waters that flow in other directions we propose to gather and throw them into Haweswater.

338. But taking the gathering area due to Haweswater itself, and taking the whole leakage of the whole of that district and the farms around it, did it not occur to you that the discharge from the lake itself was exceedingly small?—There was a very large river coming out of it when I was there, and undoubtedly that would vary; but the actual gathering ground of Haweswater is nothing like that we propose to make.

339. I am now speaking of the discharge from the lake itself?—But you will observe that when we have brought the water to it, that is to be added to it, it will discharge an immense deal more than it does now. Its present gathering ground individually is comparatively small, but we propose to make it a gathering ground of 38 square miles by the process which I am about to explain.

340. Then, in point of fact, with regard to absorption and evaporation, you have no positive rule to

G. W. Hemans, Esq.

13 Feb. 1867.

guide you in making the calculation as to how much would be taken from the 77 inches of fall?—I would hardly admit that because by the general rule which is adopted by engineers it would vary from 12 to 19 inches, according to the nature of the ground. I believe that 19 inches is quite the maximum, and the minimum may be called 11 or 12 inches, and anything between those figures may be taken according to your judgment, and according to the district in which you are working.

341. (*Mr. Prestwich.*) In Cumberland and Wales are there any large peat beds or bogs that absorb the water?—No.

342. But the mountains in both districts are covered, are they not, with heath, which, though not very thick, is very retentive of water, and the water is held there and exposed to a considerable amount of evaporation?—I think that great portions of our district, which are extremely lofty, are almost denuded of heath. There is a great deal of heath in the district, undoubtedly, but I think it will be found that great portions of it are bare rocks.

343. (*Sir J. Thwaites.*) With regard to the absorbing quality of the peat, that would depend, would it not, upon whether the basin was really full, because if it were filled that absorption would stop?—But the peat does not always lie in basins.

544. There is a considerable amount of peat in the contemplated district, is there not?—We think not. I have been over the district myself, and Mr. Hassard will tell you that he has been over it more than once.

345. Take Bampton Common, just above Haweswater. There is a large quantity of peat there, is there not?—There are peat beds, but in comparison to the enormous area of 177 square miles they are small.

346. And between Haweswater and Ulleswater, is not the whole of that district full of peat?—If you walked it over I think you would find that you could hardly say that the whole of it was full of peat.

347. I do not say the whole of it, because the upper part is a ridge of rock cropping out of the surface; but there is a considerable amount of peat there?—I am very glad to see that you know the district so well, and I hope the whole of the Commission will visit it, and apply their observations to these matters.

348. (*Chairman.*) Will you describe the district from which you propose to bring the water, the size of the reservoirs, their position, the direction in which the natural drainage of the ground goes, and also generally what the soil is composed of?—We propose using the three lakes of Haweswater, Ulleswater, and Thirlmere. Haweswater Lake is 694 feet high, and its surface is 683 acres. Ulleswater Lake is 480 feet high, and its surface of water 2,300 acres. Thirlmere Lake is 533 feet high, and its surface is 875 acres. The Commissioners will observe that Haweswater and Thirlmere are both considerably higher than Ulleswater, and I was about to show that both of them are simply used for the purpose of keeping up the supply in Ulleswater, and not to be drawn from themselves towards London. We commence at a point called Cooper's Green by making a catchwater conduit which will convey all the water of this district of Swindale, and above it to the point marked on the map where a reservoir may be made.

349. When you say that a reservoir may be made do you mean that it will be made?—It may not be necessary to make it at once, but it can be made whenever the supply of 250,000,000 gallons is required. If the supply remains at only 200,000,000 gallons, that reservoir of course may not be required. Still it may be useful hereafter.

350. What would be the size of that reservoir if required for 250,000,000 gallons?—I shall get Mr. Hassard to make a note of that, and give it to the Commission. We have only considered it at the present moment as a thing that may be required. We commence by taking up the water at Cooper's Green and Swindale Common, and carrying it to a point on Swindale Beck, and then from Swindale Beck we continue that conduit into Haweswater, and throw all the water of that district of Swindale Common into Haweswater. We then go to Helton Dale Beck to the north of Haweswater, and take in Gill Beck and Hows Beck, which are two streams above, and we throw them with all the district belonging to them also into Haweswater, and Haweswater will be raised 42 feet in order to contain those additional waters. We then from the embankment which supports those waters let off a sufficient quantity to keep the supply of the river Lowther, which we have originally taken at Cooper's Green to carry the water down the river Lowther, and pass Lowther Castle, which is the property of Lord Lonsdale, to a point near Clifton below Askham, and at that point there will be a waste weir, and at that waste weir another conduit will be made to conduct a certain portion of all those waters into Ulleswater near Pooley Bridge.

351. (*Sir J. Thwaites.*) How far are you opposite the castle from the beck?—I suppose it would be about a mile and a half below the castle. All the waters that are required for compensation to the river Lowther would pass over this gauge weir, and would continue to flow down the river Lowther. That would be 28 inches, or whatever the amount may be which I alluded to before as compensation water, which would run away as before into the river Lowther.

352. (*Chairman.*) You stated that you raise Haweswater 42 feet, do you mean the depths of the water, or the banks, or what?—42 feet will be the additional height of the water in the lake as compared with its present surface.

353. (*Mr. Harrison.*) With an embankment across the mouth of it?—Yes. The surface of the lake would be 42 feet higher than it was before.

354. (*Chairman.*) How do you propose to confine the waters within that Haweswater Lake?—We propose to make a short embankment across the gorge—Haweswater is a very narrow lake—and at the end of it, where the Haweswater River runs out, there is a narrow gorge some 300 feet wide, across which we make an embankment 42 feet high to confine this water.

355. (*Sir J. Thwaites.*) What will you do with all those little farms at the side of the water up towards Mardale?—The farm property that we take is very small, and some as you see will not be touched at all by the raising of the embankment. But Mr. Hassard will give the details of the arrangements with regard to this, and he will state what quantity those amount to.

356. (*Chairman.*) It will be merely necessary to place an embankment over the gorge 300 feet across, and an embankment 42 feet high would confine within Haweswater the additional amount of water that you put into it?—Yes.

357. That is to say, the sides of the lake are so precipitous on three sides that they do not require any more embanking?—Just so, it is simply by placing an embankment across the gorge. I forgot to state that having done that, Haweswater will contain 1,196,000,000 cubic feet, and the drainage of 38 square miles by those catchment conduits.

358. (*Sir J. Thwaites.*) That is a provision to compensate the river Lowther also, is it not?—It is for both purposes. Part will run down the river Lowther as before, and a part will follow the line marked on the map from Clifton to Pooley Bridge, and be discharged into Ulleswater.

359. What is the daily additional water that you would permit to flow over into the river Lowther?—It would be the whole excess, whatever the level is at the time above the 36½ inches that we want.

360. When it masters your storing power of course it will flow over; but I am speaking now of the dry weather discharge?—In dry weather, if we take 48 inches, the discharge is the difference between the loss of what we take and that 48 inches; and if the dry-weather fall is only 60 or 61 inches there will be about 12 inches to go off. I think that Professor Symons

makes the dry-weather rainfall 62 inches, but I am not quite certain. Whatever that is it is the difference between that and 48½ inches which will go then to the compensation.

361. Will you in dry weather diminish or increase the quantity of water flowing down the river Lowther?—In dry weather we shall increase the quantity of water flowing down the river Lowther.

362. You mean that you will equalize it?—Yes, we shall equalize it; because, as you will observe, we have stored it up in Haweswater, and we should give it them when they would not have it from the skies. Before going to Ulleswater I will go on to the Thirlmere gathering ground. At the point called the Barrow Beck we make a conduit which follows the red line on the map, and takes up the Mosedale Beck and keeps running round the gathering ground by the High Fells, and discharges all the water that falls on Matterdale Common into Thirlmere. We then go south, and there is a wet district of 6 square miles, which is gathered by two conduits; and having been collected at the point which you see marked on the map, instead of going to Ambleside southwards, all that water is thrown back by a tunnel into Thirlmere. And Thirlmere is raised 64 feet by an embankment at the north end in a similar manner to what I described at Haweswater. At Cold Barrow Fell another of those catchwater conduits is made passing by Wyth Burn and by Bleaberry Fell with a branch out towards Keswick, and all those waters are collected and carried to the north end of Thirlmere also, and then Thirlmere will contain 1,722,000,000 cubic feet.

363. (*Col. Harness.*) Do you propose to give any compensation to those streams which have been turned from the south to Thirlmere?—No, we have not considered it necessary to propose any compensation for that; it is a small stream, without any mills or works upon it; but that might be done if it is discovered to be necessary.

364. (*Sir J. Thwaites.*) Before it comes to an important stream there are some tributaries to it, are there not?—Yes, there are some tributaries and there is a gathering ground still left upon it, so that it might not be necessary to provide for compensation.

365. You propose, do you not, to raise Thirlmere 64 feet?—Yes.

366. At the end is it not very narrow?—Yes, quite a gorge.

367. How do you propose to deal with the road close to the lake?—The road will have to be raised to the margin of the new lake.

368. How will you get the road up to 64 feet?—The whole of that road rises most rapidly as you get towards Ambleside, and that country it rises very considerably. You go up a very steep hill for a great way, and if we make a gradual incline along the margin of the lake we shall improve the road.

369. You will have to remove several houses, will you not?—There are some houses to be removed. Mr. Hassard will give the details of that. I have been all along the route, but I have not got a list of the houses myself. Then it is proposed that there should be also a gauge at the north end of Thirlmere. A portion of the compensation water will be let off there and accumulate in a reservoir on what is called the St. John's Beck, and that will be used for a compensating water reservoir for the Greta River, upon which there are some small mills near Keswick.

370. (*Chairman.*) What is to be the size of that reservoir?—That reservoir is to contain 380,000,000 cubic feet.

371. (*Sir J. Thwaites.*) Is that the discharging capacity or the holding capacity?—That is the holding capacity.

372. What is the discharging capacity?—The discharging capacity must be the surplus that that will give us.

373. Can you discharge to a certain depth?—I cannot give you that; but any details of that kind Mr. Hassard has worked up and will give the Commissioners. I do not remember at this moment what the discharging level of that reservoir is. Then we have collected the waters in that district of 44 square miles into Thirlmere, which will now be conveyed by an outlet conduit and tunnel into Ulleswater. That line of conduit runs from the north end of Thirlmere round by Matterdale Beck and Dacre Beck, and discharges into the north end of Ulleswater.

374. Do you tunnel through the whole of it?—Yes, we tunnel through the whole of that dotted part.

375. Is not it limestone in that district?—No, it is all Silurian ground. We have no limestone in the district.

376. (*Mr. Prestwich.*) What scale is that map on the wall?—6 inches to the mile.

377. (*Chairman.*) What is the length of the tunnel through Matterdale?—That tunnel would be seven miles, but it is a shallow tunnel, and it is merely dependent upon the number of shafts. There is no difficulty in a shallow tunnel. The deepest shaft would be 400 feet. We have now got the 38 square miles of Haweswater, and the 44 square miles of Thirlmere delivered into Ulleswater.

378. As I understand you first of all, you take the drainage of 44 square miles and put it into Thirlmere first, and then you take it out again?—Yes, in order to bring it to Ulleswater, which is our supply reservoir. The other two are only to maintain the level of Ulleswater. Ulleswater itself is to be what may be called the London reservoir. The others are only to keep it supplied, the great object of that being to avoid, as much as possible, the alteration of the level of Ulleswater, which is a romantic and beautiful lake. Those other two are lakes not frequented; they are without hotels and accommodation, or any particular beauty about them. They are not those lakes that people frequent, and therefore altering their levels is of no consequence in a scenic point of view, which would not be the case with regard to Ulleswater, because it is a very beautiful lake, and the object there is to keep the level even as much as we can. It will be observed that the natural drainage of all these lakes is northward, but we would propose having stored all this water in Ulleswater to take it southward. Ulleswater itself possesses a gathering area of 95 square miles, and it could be raised five feet above its average winter level, and would then contain 1,742,000,000 cubic feet.

379. (*Col. Harness.*) To what extent do you propose to consider it available?—Twelve feet below its present level.

380. (*Sir J. Thwaites.*) You will tap it to that depth?—Yes.

381. That will be seven feet below the present level?—No, we raise it five feet and take 17 from it, and that leaves 12 below the present level.

382. Can you raise it five feet without interfering with the houses which are on the lake?—Yes. By making a very slight embankment at the south end, and throwing the drainage of all the Patterdale district into one tunnel, we can protect that portion entirely. It will have no ugly appearance, nor will it injure or flood the property at all.

383. Take Mr. Marshall's house for example, will not five feet carry the water into his ground?—No, not if we bank it out.

384. But you will put his property below the level of the lake water?—No. I think that five feet will not put it below the level of the lake water. I think it will still be above the lake. There are some meadows close to the lake which five feet will cover, and which I believe are sometimes covered in a high winter flood now; but we should keep them dry by an embankment.

385. (*Chairman.*) What would be the height of the embankment which you propose to put at the south end?—It would raise the water five feet, but the embankment itself might be seven or eight feet high.

G. W. Hemans, Esq.

13 Feb. 1867.

386. Would that be the winter level of the water?—I imagine that the winter level of the water would be very nearly that in very wet seasons, but perhaps not quite so much.

387. Then you propose to add to that, do you not?—No, to add to the average winter level, not to the extreme winter level. The extreme winter level at present, in Ulleswater, sometimes covers the road from Patterdale.

388. You propose to add five feet to the average winter level, but when the lake rises to what is not the average but an extraordinary winter level, what will happen?—I do not think that we shall make it much worse than it was before, because we shall never exceed the five feet above the average winter level. We shall not increase it, for if more water comes down we shall not use it, but we shall pass it away by this culvert.

389. When you propose to raise it five feet above the average winter level, you mean that you will put five feet more water than the average winter level?—Yes.

390. Then when the water is at an extraordinary winter level, you would be five feet over and above that again, would you not?—No, certainly not, because we should not allow the water to go in. We should be much more likely to make the lake more secure in winter than it is now.

391. How will you do that?—Because we shall regulate it by putting a weir at Clifton. We shall prevent any additional water going in by passing it down the river Lowther, if we find it going above the level which we maintain, and which we mean to be permanent, that is to say, when we are not in drought.

392. (*Sir J. Thwaites.*) You will have a strong overflow at that point?—Yes, and we shall do the same at Thirlmere.

393. (*Chairman.*) What you mean is, that the lake will never be more than five feet above the average winter level?—No, we profess that we can maintain it rigidly at that level, except when it has to be lower than that. When there is a drought we may have to lower it, but it will never rise above that. We draw off the water at the southern end, and we prevent its entrance at the northern end, so that we have power to regulate it absolutely.

394. (*Sir J. Thwaites.*) Have you ascertained to what height the floods in the winter will raise the lake?—Vaguely. Local information about floods is always rather vague, but we ascertained that very high floods frequently covered the high road to Patterdale.

395. Have you observed upon the upper part of the lake, on the opposite side, a rock upon which the heights of the floods have been marked?—Yes. I do not recollect observing the exact height, but I did see the rock. I think Mr. Hassard may be able to give that information.

396. If you give an increase of five feet, will you not flood the district when the floods are more than the ordinary winter floods?—Yes, but I was explaining that we cannot flood the district if we bank it up, and we shall protect it by an embankment at the south end of the lake.

397. You propose to raise the level five feet. That will increase the quantity of water, and will not, therefore, the quantity of water in the winter floods, which you cannot pass, be increased by your embankment?—Our embankment and our means of drawing and regulating both the outlet and inlet will make it impossible for those floods to rise; we can regulate those floods absolutely.

398. (*Mr. Harrison.*) If I understand you, the main embankment will be at the northern end, at Pooley Bridge, and the embankment to which you are referring, at the south end, will be simply for the purpose of protecting some low grounds?—Yes, simply for that purpose. The embankment to the north is a very slight affair. There is already a ridge there with only an opening for the river to pass through, and at the south end the object would simply be to protect the Patterdale meadows, and prevent the five feet from running into those grounds.

399. (*Sir J. Thwaites.*) How will the inn at Pooley Bridge be affected?—The inn at Pooley Bridge is below our banks. There is a bridge there, and the inn is below that bridge; we shall not encroach upon the inn at all. Then our plan is to reverse the drainage towards London instead of allowing it to flow northwards as it does at present, and for that purpose we have to make a long tunnel under Kirkstone Pass. The total length of that deep rock cutting will be more than seven miles, and of that seven miles five miles will be in tunnel, and out of the five miles one and three-quarter miles will be incapable of having shafts sunk, on account of the great height of the mountain above, and therefore that becomes the measure of the work.

400. That is the highest part of England, is it not?—I am not aware whether it is the highest pass in England, but it is a very lofty pass, and the height of the pass will preclude the sinking of the shafts in a mile and three-quarters out of that five miles of tunnel. That, then, becomes the measure of the work in point of time. The size of the tunnel will be 20 feet by 15 feet, and I may as well mention that among the many works which I have constructed I have within the last few years made a long tunnel in Silurian slate of the same description in one of my railways in Ireland, about a mile in length, and I am well acquainted with that rock and the rate at which it can be worked, and, although the tunnel which I constructed was not done with anything like the rapidity with which we should propose to construct this, I am able to say from experience of the Mont Cenis tunnel, that if we proceed at the rate at which they have been able to do, we should complete that mile and three-quarters in three years.

401. (*Chairman.*) Could you give us the rate at which they have been able to work in the Mont Cenis case?—We will put in a table showing the rate at which they have been able to work.

402. (*Sir J. Thwaites.*) You will only have two faces, and in the Mont Cenis tunnel they bore at the rate of a yard and a half a day at each face on the average, I believe?—Yes, about a yard and a half a day. They use very beautiful machinery there for drilling holes, and they get on in a way which I never saw done in tunnelling before.

403. When you come out of the tunnel at Ambleside you approach Lake Windermere, do you not?—Yes. I propose, if the Commission will allow me, to leave the description of the aqueduct and some other matters connected with the business to Mr. Hassard, who has worked up a great many more details than I have, and will be able to give them better. I think I have given every description about the lakes. I might observe here that Professor Way's analysis of the water is given in my pamphlet.

404. (*Chairman.*) You propose that Professor Way should be examined, do you not?—I am not certain that he will be able to appear; he is out of London at present, but if he returns it will be better that he should be examined. I can send in his original letter to me with his analysis in it, and then he can be examined upon it at length. He gives a most favourable account of the water, as being the very best for the purpose.

405. Can you give the Commission any evidence with regard to the existence of any lead mines in the neighbourhood of Ulleswater?—Yes, there is a lead mine on Glenridding Beck, which at present discharges itself into the stream which runs into Ulleswater. There is no lead in that stream, I believe, but there is all the foul washing of the matrix in which the lead is found, and that gives round the mouth of the stream a very ugly appearance to the water; but there are many ways of dealing with that. We can lead that water away either round the lake

in a pipe, because a moderate pipe will take that foul water, or we can take it in a pipe along our own tunnel, or we may use settling ponds and let that foul water settle.

406. Supposing that you carried that foul water by a tunnel or pipe round the lake, would not that reduce the quantity of water that there would be in the lake? —Not to any extent worth mentioning. We think that an 18-inch pipe would take all the water necessary for washing the ores. At present it looks very formidable, because they simply turn their foul washing into the pure water, and this comes into the lake, and all the river water is foul.

407. Do you propose, when you say that you will carry it by a pipe round the lake, to divert that large river?—No, only the portion of water that is necessary for the washing of the ores.

408. (*Sir J. Thwaites.*) I presume that Professor Way can give us his opinion as to the effect of that colouring matter on health?—No doubt; but I think the best manner to treat that will be in the first place to use several settling ponds, and we should probably deliver that water after passing through them clear into the lake, but if there remained still a trace of lead of any kind we should then have to pipe it away.

409. Where is the lead through which this water goes for washing the ore?—The washing takes place at the mills on the stream, on the spot.

410. (*Mr. Prestwich.*) What distance up the stream? —I think it is about three miles up the stream. There is another not quite so extensive mine on the other side of the ridge of Helvellyn, which delivers water into Thirlmere, which would be treated in the same way, either by piping it away to some of our outlets, or else by settling ponds; but I think it will be found that there is little or no lead in that washing, but merely the clay which the lead is in.

411. (*Sir J. Thwaites.*) Still it discolours the upper part of the lake?—Yes, and people who pass it without any knowledge think that it is all lead and all poison, but I may observe that the favourite spot for fishing is just round the mouth of that river; the fish seem to find something in that clay which they like, because it is there that people fish, and I do not believe that there is anything really injurious in that water.

412. (*Mr. Harrison.*) What is the probability of other lead mines in future years being opened out in that district?—That is a question which I am afraid I am not able to give any very satisfactory answer to that is worth much, but it is my opinion that if a reservoir like this should be made for the supply of London, no lead mines ought to be allowed in that district.

413. Would not the owners of those mines be entitled to claim compensation at once for that?—It is very doubtful whether they would be entitled to claim compensation considering that they have no right as I think to foul by their washings any water used by the public. If it should turn out, as I think it very probable it may, that those washings can be conducted without in the least fouling the water of the lake, there is an end of the case, but if not it seems to me very doubtful what right any parties can have to put up works to foul a supply of pure water to the public.

414. (*Chairman.*) Is there any other point upon which you wish to give evidence?—I find, as I think Mr. Bateman did, that an average rate of 10*d.* in the pound with the sale of water on the way would amply cover the interest on the amount of money required and the expenses of doing the work.

415. It is rather vague to speak of a 10*d.* rate and the sale of water on the way, ought you not rather to tell us what towns you propose to supply, and the cost of supplying each of those towns?—I am afraid that I cannot state precisely the towns that we are going to deal with, because we should have to communicate with them. We assume 50,000,000 gallons a day for the supply of other towns.

416. (*Sir J. Thwaites.*) You state that that 10*d.* rate which you propose to charge is after deducting the price which you receive for the water that you distribute on the way?—Yes.

417. But you cannot say how much you will receive for water distributed short of the metropolis?—I will give that. We assume a sale of 50,000,000 gallons, but we are not able to say where it will be distributed, but it will be somewhere on the way. It is not much to assume that 50,000,000 gallons of water a day in those populous districts will be readily taken at 3*d.* per 1,000 gallons which is a very moderate price. That would give an income of 228,125*l.* per annum, and we estimate the cost of the whole of our works at 13,500,000*l.* which at four per cent. would require 540,000*l.* per annum, and we assume that the cost of collection would be 100,000*l.* per annum, and that the dividends to the water companies would be 425,000*l.* per annum, making a total annual charge of 1,065,000*l.*

418. (*Sir B. Phillips.*) But you take this 10*d.* rate, do you not, on a gross valuation of 20,000,000*l.*?— Yes, it being between 15,000,000*l.* and 16,000,000*l.* now.

419. The present valuation, I believe, is only 15,500,000*l.*?—I think it is nearly 16,000,000*l.*, but we are assuming an increase of demand at a less rate than it is now proceeding at.

420. (*Sir J. Thwaites.*) Are you of opinion that the works will take four or five years to complete?— Yes. When we talk of four or five years from the present time, I should say there may not be much probability that the power could be obtained and everything settled in less than ten years from the present day, or in eight or nine years at all events, so that I think it is not too much to expect that the valuation would be 20,000,000*l.* Then 20,000,000*l.* would give 833,333*l.* a year at 10*d.*; the sale of the water on the way would give 228,125*l.* as I stated before, and the sale for trades purposes, if the amount is at all in the same proportion as in other towns, would amount to 250,000*l.* a year, making a total of 1,311,458*l.* per annum, and showing a very large surplus over the annual charges.

421. (*Chairman.*) Then are we to understand that Mr. Hassard will give reasons for supposing that the rainfall in the Welsh district is not sufficient?—Yes; we consider that the observations in the Welsh districts have not been at all sufficiently long; they have been only during three months in the district in question, and those were three very wet months, and they are hardly sufficient to go upon for the rainfall.

422. (*Mr. Harrison.*) Mr. Bateman stated that they were not wet months in that particular district?—We have compared the rainfall in those three months from the table of the rainfalls all over the country, and we find that those three months in almost every district were nearly half the whole rainfall of the year. I have here a sheet published by Mr. Fletcher, of the rainfall in Cumberland and Westmoreland, in which you find that at every station almost the rainfall during those three months was nearly half the rainfall of the whole year.

423. (*Chairman.*) Taking that particular district in Wales, was it so?—That I am not able to say. If Mr. Bateman says it is not so, his evidence is worth more than mine, because I do not know it.

424. (*Mr. Harrison.*) In the north of England we have had an enormous rainfall when in several parts of the south-east of England it has been comparatively small; might not that be the case in Wales? —I cannot give you information upon that. Mr. Bateman knows that better than I do.

425. (*Chairman.*) You wish us to understand that you will not contradict Mr. Bateman?—Precisely so.

426. (*Sir J. Thwaites.*) But am I to understand you to make this statement, that the gauging in question was simply during three months?—Yes,

G. W. Hemans, Esq.
13 Feb. 1867.

that is as I understood Mr. Bateman's evidence, that the district had only been gauged during three months.

427. And that during those three months there was a very heavy fall of rain?—It was unquestionably very wet in many parts of England, and my decided opinion is that three months gauging is entirely inadequate to enable one to decide upon a question of this great importance.

428. (*Chairman.*) You are not prepared to say whether or not it was an excessive rainfall or the reverse in that particular district?—No, I cannot state that. I can state that in the north it was an excessive rainfall, equal to half the rainfall of the whole year. I may perhaps observe that we propose using in part of our works instead of cast-iron pipes wrought-iron pipes of great diameter, which we think will be a great economy, and we want to show that by rendering it inside with Portland cement, that kind of pipe will have no danger whatever of oxidation. We have brought a sample of the pipe, which we should be very much obliged if the Commission would look at.

429. (*Sir J. Thwaites.*) Will the cement stand?—It can all be done as that sample is, and you will not have the slightest doubt of its standing. Portland cement is improving immensely every year in its manufacture, and we believe that it will be an admirable way of doing it; the rendering is half an inch thick that we put in, and if you can have an eight foot pipe of wrought iron you will greatly improve the working, because it will admit of much greater velocity of current. It is a great advantage to have pipes in wrought iron, which can be made so much lighter and so much less weight to carry.

430. (*Mr. Harrison.*) Your proposed mode of conducting the water in your conduit differs from that of Mr. Bateman from the fact of the greater distance that you have to traverse obliging you to adopt a greater fall per mile, and consequently all your works must be of greater magnitude and larger sectional area?—Yes, they must be of larger sectional area, but our mode gives us a more economical construction, because the slower the velocity the less chance there is of injury by the current of water.

431. Mr. Bateman, in his evidence, states that excepting where he goes through stone, he proposes to line his conduit from end to end with brick, and that by so doing he can adopt any velocity that he likes; do you agree with him with regard to that?—No doubt he can do so.

432. You propose to make yours a river flowing slowly, and you assume that where you pass through particular soils you may avoid the lining, although is is even through clay?—We propose to line it all the way, but not in an expensive manner, merely with the rock of the district and with hydraulic lime.

433. Do you propose to line it the whole way?—Yes, it will probably be necessary to line it the whole way. In fact it is a question of height and distance. The height of Mr. Bateman's plan is very nearly the same as ours, but our distance is longer than his, and therefore we make a rather larger conduit, but we do not make it quite so expensive.

The witness withdrew.

Adjourned to to-morrow at 11 o'clock.

Thursday, 14th February 1867.

PRESENT:

His Grace THE DUKE OF RICHMOND in the Chair.

Sir John Thwaites.
Colonel Harness.
Alderman Sir Benjamin Phillips.
Thomas Elliot Harrison, Esq.
Joseph Prestwich, Esq.

George James Symons, Esq., examined.

G. J. Symons, Esq.
14 Feb. 1867.

434. (*Chairman.*) You are a Fellow are you not of the Meteorological Society?—Yes.

435. And editor of the "British Rainfall?"—Yes.

436. And secretary to the Rainfall Committee of the British Association?—I am.

437. Have you for many years past devoted the whole of your time to the collection, classification, and discussion of the rainfall returns from all parts of the British Islands?—For many years.

438. And in different parts of the country have you upwards of 1,500 gauges at work?—I have; that is to say, returns are forwarded to me from those places, and many of the gauges are my own.

439. Are you acquainted with the whole of the Lake district?—I have walked over a great portion of it repeatedly, especially the eastern portion.

440. And amongst other things for the purpose of meteorological observations?—Precisely so.

441. Have you prepared an analysis of the observations which you have made bearing on the rainfall of that district?—I have prepared an analysis of every return which has been procured from any part of that district, and I have the pleasure of handing it in. (*The witness delivered in the following paper.*)

Report on the Rainfall of Parts of Cumberland and Westmoreland, by G. J. Symons, F.M.S.

The unusually complete evidence (that of 22 years, and for the whole or part of that time of 30 rain gauges) as to the rainfall in the district proposed to be taken up by Messrs. Hemans and Hassard, may be divided into two portions: 1. Discussion of old observations in and closely adjacent to the district; 2. Discussion of the results of gauges recently erected at other places within the district.

As to the first point it may be well to state (to prove, if desired) that the simple arithmetical mean of the rainfall at any place is a fallacious guide to the true mean rainfall unless it is based on a long series of years. The only mode by which observations continued only for a few months or years can be made available is by first establishing the ratio of the rainfall in those months or years to the mean of a series of years. This has been done in Table I., wherein the total rainfall in each of 22 years at three stations close to the district under consideration (in fact a triangle joining them would include much of the district) has been reduced to ratios showing at once the relation of each year to the average. The mean of the ratios of any year at the three stations has been held to indicate the true ratio of the fall in that year to the mean of the whole period of 22 years. Table II. contains *every* record of rainfall in my possession affecting the question at issue, the stations being arranged

in the order in which they are printed in my report to the British Association (1865, pages 208, 209, and 225).

The means have been taken both arithmetically, in the ordinary manner, and also reduced by the method already indicated to the true mean of 22 years.

I believe this second line of figures (those quoted on the map) shows the lowest possible mean fall at the places named. I am quite certain the errors are in defect rather than in excess, and may perhaps be permitted to point out reasons for this statement.

(1.) No correction has been applied for the elevation of the mouth of the gauges above the ground, which materially diminishes the amount collected.

(2.) No correction has been applied for errors in the gauges themselves, yet these are possibly, I might say probably, considerable. To take two instances only, Greystoke and Hallsteads. At the former the instrument is of the pattern known as Crosley's patent rain gauge, a clockwork contrivance, which meteorologists have long rejected for its errors; at Hallsteads the gauge is similar to the one at Crow Park, Keswick, which, by reference to the tables, will be seen to record about 14 per cent. too little. This would raise the fall at Hallsteads to 61 inches.

(3.) Several of the years forming the 22 years' average, adopted as the standard of reference, were exceptionally, if not unprecedentedly, dry, and I may add that I have previously shown (British Association Report, 1865, p. 203) that the years in question are far below the average of the 50 years 1815 to 1864.

I believe that these three sources of diminution may be approximately taken at 10 per cent., and that at the comparatively dry spots (therefore selected as residences), where observations have been made for many years, good gauges, well placed and properly attended to, would show a fall at least one-tenth greater than that shown on the map.

I may here appropriately offer a few remarks on droughts in the Lake district. Those at Seathwaite in ten years ending 1859 were—

						inches.
1852	-	Feb. 18	to April 28	-	69 days	- 1·06
1854	-	April 1	to April 26	-	25 „	- 0·70
1855	-	Nov. 13	to Dec. 22	-	39 „	- 1·40
1857	-	June 12	to June 28	-	16 „	- 0·00
1858	-	Feb. 14	to March 4	-	18 „	- 0·00
1858	-	Oct. 28	to Nov. 24	-	27 „	- 0·13
1859	-	June 29	to July 19	-	20 „	- 0·00

There was therefore only one drought of more than 40 days and more than an inch of rain fell during its continuance.

Further information is afforded by the subjoined table, which shows the rainfall in the two driest consecutive months at each of the undermentioned stations:—

1852. March and April.		1861. April and May.	
Stye Head - -	1·64	Mire House - -	2·37
Lesketh Howe -	1·14	Low Nook - -	2·45
Selside - - -	1·49	Grasmere - -	2·33
Stonethwaite - -	1·41	Lough Rigg - -	2·35
The Stye - - -	1·78	Lancregg - -	2·83
The Howe - -	1·22	Patterdale - -	·72
Keswick - -	·94	Hallsteads - -	0·00
Seathwaite - -	1·72	Watermilloch -	2·50
Penrith - - -	1·03		

Hence we see there is only one instance of two months without rain, and that is unsupported by the returns from the nearest station. Moreover, it will be noticed that these droughts—the only ones on record in the district—occurred in the two years remarkable for the largest yearly totals.

TABLE I.

DETERMINATION of the RATIO of the RAINFALL in each of 22 Years to the Mean of the whole Period 1845 to 1866.

YEAR.	Rainfall in each Year.			Ratio at each Station.			Mean Ratio.
	The Howe Troutbeck, Windermere.	Scathwaite, Borrowdale.	Keswick.	The Howe Troutbeck.	Scathwaite, Borrowdale.	Keswick.	
	In.	In.	In.				
1845	76·30	151·87	62·20	96	108	106	103
1846	77·71	143·51	67·68	97	103	116	105
1847	78·00	129·24	58·28	98	92	100	97
1848	91·34	160·89	66·41	114	115	113	114
1849	75·42	125·47	48·80	94	90	83	89
1850	79·81	143·96	59·53	100	103	102	102
1851	80·77	139·60	62·34	101	100	106	102
1852	115·62	156·74	79·97	145	112	137	131
1853	65·97	113·69	50·45	83	81	86	83
1854	65·95	143·48	46·82	83	103	80	89
1855	47·54	88·31	37·40	60	63	64	62
1856	55·28	105·52	47·55	69	75	81	75
1857	55·30	116·60	48·88	69	83	84	79
1858	60·07	114·61	50·27	75	82	86	81
1859	94·95	147·29	66·89	119	105	114	113
1860	102·58	142·20	54·17	129	102	93	108
1861	116·26	182·58	74·42	146	130	127	134
1862	94·27	170·03	61·37	118	121	105	115
1863	84·97	173·84	71·54	106	124	122	117
1864	75·74	134·67	52·68	95	84	90	90
1865	64·05	117·49	49·18	80	96	84	87
1866	98·69	179·12	70·81	124	128	121	124
Mean.	79·85	140·03	58·53	—	—	—	—

TABLE II.

Date.	Ratio.	Seatoller.	Stonethwaite.	Stonethwaite.	The Stye.	The Stye.	Stye Head Tarn.	Stye Head Tarn.	Derwent Island, Keswick.	Crow Park, Keswick.	Bassenthwaite Hall.	Mire House, Bassenthwaite.	Penrith.	Penrith, Edenhall.	Penrith, Greystoke.
Above ground - -		1 ft.	1 ft.	6 in.	1 ft.	6 in.	1 ft.	6 in.	1 ft.	4 ft.	—	7 in.	—	1 ft.	5 ft.
Above sea - - -		1,388 ft.	280 ft.	330 ft.	948 ft.	1,077 ft.	1,448 ft.	1,472 ft.	240 ft.	260 ft.	250 ft.	310 ft.	420 feet.	334 ft.	700 ft.
Authority - - -		Dr. Miller.	Dr. Miller.	I. Fletcher, Esq.	Dr. Miller.	I. Fletcher, Esq.	Dr. Miller.	I. Fletcher, Esq.	H. C. Marshall, Esq.	H. C. Marshall, Esq.	Dr. Miller.	J. Spedding, Esq.	Mr. Bird.	Mr. Bowstead.	—
1845	103	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1846	105	—	—	—	—	—	—	—	—	—	—	—	—	—	56·76
1847	97	105·74	106·21	—	—	—	112·43	—	—	—	44·45	—	—	—	37·79
1848	114	126·95	130·24	—	—	—	124·95	—	—	—	47·06	—	—	—	44·02
1849	89	100·16	94·27	—	—	—	97·21	—	—	—	40·00	—	—	—	36·39
1850	102	147·65	105·81	—	—	—	—	—	—	—	46·97	—	—	—	43·04
1851	102	141·42	114·12	—	169·62	—	100·16	—	—	—	45·41	—	36·24	—	38·58
1852	131	156·59	133·86	—	167·73	—	124·19	—	—	—	59·71	—	51·12	—	57·98
1853	83	111·45	95·65	—	124·91	—	92·65	—	—	—	—	—	30·13	—	38·23
1854	89	—	—	—	153·52	—	—	—	—	—	—	48·51	34·71	—	29·10
1855	62	—	—	—	99·16	—	—	—	—	—	—	33·16	—	—	29·88
1856	75	—	—	—	113·11	—	—	—	—	—	—	43·16	—	—	36·56
1857	79	—	—	—	116·20	—	—	—	—	—	—	40·57	—	—	35·20
1858	81	—	—	—	—	—	—	—	—	—	—	42·22	—	—	33·43
1859	113	—	—	—	—	—	—	—	—	—	—	50·94	—	—	44·00
1860	108	—	—	—	—	—	—	—	—	—	—	49·79	—	—	43·86
1861	134	—	—	—	—	—	—	—	—	—	—	60·35	—	—	44·37
1862	115	—	—	—	—	—	—	—	—	—	—	55·29	—	—	43·82
1863	117	—	—	—	—	—	—	—	—	—	—	63·70	—	—	49·73
1864	90	—	—	100·76	—	—	—	103·73	—	—	—	46·42	—	28·61	34·15
1865	87	—	—	84·13	—	149·07	—	99·85	49·23	43·00	—	42·63	—	28·99	33·34
1866	124	—	—	131·11	—	224·56	—	135·06	70·45	64·30	—	62·53	—	36·75	—
Arithmetical mean		127·14	111·45	105·33	134·89	186·81	108·60	114·54	59·84	53·65	47·27	49·17	38·05	31·45	40·51
True mean - -		123·43	108·20	105·01	151·56	177·91	105·42	114·08	56·99	51·43	44·59	50·17	37·67	31·36	41·16
			106·60		164·73		109·75								

TABLE II.—*continued.*

Date.	Ratio.	Penrith Tirril.	Ambleside, Lesketh Howe.	Ambleside, Lough Rigg.	Ambleside, Low Nook.	Penrith, Easemere Hill.	Grasmere, Parsonage.	Grasmere.	Grasmere, Lanercgg.	Penrith, Great Strickland.	Penrith, Hallsteads.	Kendal, Low Bridge Ho., Selside.	Penrith, Lowther Castle.	Ulleswater, Patterdale.	Watermilloch.
Above Ground - - Above Sea - - - Authority - - -		— — —	3 ft. 200 feet. Dr. Davy. F.R.S.	9 in. 570 ft. E. Balme, Esq.	1 ft. 2 in. 150 ft. J. Wilson, Esq.	3 ft. 560 ft. Mrs. Angas.	— 180 ft. Dr. Miller.	— 240 ft. J. S. Green.	4 ft. 6 in. — Sir J. Richardson.	1 ft. 6 in. 647 ft. H. H. Plumer, Esq.	4 ft. 480 ft. W. Marshall, Esq., M.P.	— 736 ft. —	4 ft. 840 ft. J. Parkes, C.E.	2 ft. 500 ft. W. Marshall, Esq., M.P.	3 ft. 6 in. 720 ft. Mr. Rumney.
1845	103	40·00	—	—	—	—	121·00	—	—	—	52·60	—	—	—	—
1846	105	—	—	—	—	—	110·32	—	—	—	57·10	—	—	—	—
1847	97	—	—	—	—	—	93·33	—	—	—	56·90	71·10	—	—	—
1848	114	—	77·04	—	—	—	—	—	—	—	61·20	80·12	—	—	—
1849	89	—	65·38	—	—	—	—	—	—	—	47·80	70·39	—	—	—
1850	102	—	79·85	—	—	—	—	—	—	—	—	76·39	—	—	—
1851	102	—	84·22	—	—	—	—	—	—	—	—	70·58	—	—	—
1852	131	—	104·33	—	—	—	—	—	—	—	—	92·48	—	—	—
1853	83	—	68·20	—	—	—	—	—	—	—	—	57·98	—	—	—
1854	89	—	85·63	—	—	—	—	—	—	—	38·20	70·51	—	—	—
1855	62	—	53·67	—	—	—	—	—	—	—	43·50	—	—	—	—
1856	75	—	56·54	—	—	—	—	—	—	—	44·80	—	—	—	—
1857	79	—	62·52	—	—	—	—	—	—	—	38·80	—	—	—	—
1858	81	—	64·15	—	—	—	—	—	—	—	39·50	—	—	57·50	—
1859	113	—	84·03	—	—	—	—	—	—	—	47·60	—	—	—	—
1860	108	—	79·97	—	73·25	—	—	—	104·87	—	46·90	—	45·33	—	60·10
1861	134	—	98·03	93·75	101·40	—	—	—	123·22	—	59·90	—	—	99·83	66·60
1862	115	—	88·26	—	86·10	—	—	87·23	—	—	63·20	—	—	—	65·50
1863	117	—	81·69	86·34	85·50	50·45	—	—	—	—	64·90	—	—	88·90	61·40
1864	90	—	74·09	74·63	74·40	—	—	—	—	—	55·40	—	45·76	61·49	52·90
1865	87	—	65·80	71·00	65·78	—	—	—	—	35·87	49·00	—	35·08	61·99	53·00
1866	124	—	99·81	97·05	94·27	—	—	—	—	46·00	67·50	—	—	101·03	65 20
Arithmetical Mean		40·00	77·54	84·55	82·96	50·45	108·22	87·23	114·05	40·94	51·92	73·69	42·06	78·46	60·67
True Mean - -		38·83	77·58	76·86	74·74	43·12	106·09	85·85	94·25	38·62	52·44	72·96	44·26	74·72	54·66

G. J. Symons, Esq.

14 Feb. 1867.

TABLE III.

The second portion of evidence is that from gauges erected in September 1866. The following table gives the results to January 1, 1867.

Position.	Height of Gauge. Above ground.	Height of Gauge. Above Sea level.	October.	November.	December.	Three Months.
	Ft. In.					
Watendlath - -	1 0	867	6·50	11·25	15·13	32·88
Wythburn Parsonage -	1 0	574	5·88	12·88	17·25	36·01
Helvellyn Birkside -	1 0	1,800	5·75	12·00	14·50	32·25
Matterdale - -	1 0	1,400	5·25	7·75	18·75	31·75
Gowbarrow - -	1 0	1,100	4·33	7·25	17·25	28·83
Greenside Stang End -	1 6	1,550	4·64	10·44	11·70	26·78
Do. Mills -	1 0	1,000	6·74	12·99	17·45	37·18
Swarth Fell - -	1 0	1,000	3·50	5·50	7·00	16·00
Measand Becks -	1 0	1,200	3·50	4·50	7·50	15·50
Mardale Green - -	1 0	800	3·75	12·25	16·50	32·50
Wet Sleddale - -	1 0	1,500	7·75	10·50	15·75	34·00
Kirkstone Pass -	1 0	1,500	7·25	12·00	13·50	32·75
Easedale Tarn - -	1 0	1,175	7·50	14·25	18·25	40·00
Average - -	1 0	1,190	5·57	10·27	14·65	30·49

The rainfall in the three months October, November, December, in mountain regions is very nearly 30 per cent. of the total yearly fall. If this rough, but convenient rule, were applied to the preceding observations, they would give for the district a mean annual rainfall of 100 inches. But, in spite of the dryness of October, it might be argued that they were three wet months. I purpose to ascertain from the records of the old established stations, exactly the real per centage of these identical three months, so that there can be no possibility of doubt.

RAINFALL, October to December 1866, at the undermentioned stations, compared with the average at those stations.

——	Oct.-Dec. 1866.	Average from Tables I. & II.	Percentage in Oct.-Dec. 1866.
Scathwaite - -	58·09	140·03	41
Ambleside - -	29·17	76·86	38
Keswick - -	21·82	58·53	37
Patterdale - -	28·62	74·72	38
Hallsteads - -	15·40	52·44	29
Watermillock -	18·00	54·66	33
Great Strickland -	10·84	38·62	28
Average - - -			35

We thus find that the real average was 35 per cent., about 40 per cent. at the western stations and 30 at the eastern. Applying this determination to the data in Table III. we deduce the true mean fall at each of the new stations to be as follows:

Watendlath	82 inches.	Swarthfell	53 inches.
Wythburn	90 „	Measandbecks	52 „
Birkside	81 „	Mardale Green	108 „
Matterdale	80 „	Wet Sleddale	113 „
Gowbarrow	72 „	Kirkstone Pass	82 „
Stang End	67 „	Easedale Tarn	100 „
Greenside Mills	93 „		

Mean of these 13 stations = 82 inches.

Taking the divisions of the six inch ordnance maps as subdividing the district into areas, for each of which the rainfall may be separately determined, I believe the following values are rather below the average fall in each:

Cumberland, sheet	LVII.	= 60	inches.
„ „	LVIII.	= 45	„
„ „	LXV.	= 80	„
„ „	LXVI.	= 53	„
„ „	LXX.	= 93	„
„ „	LXXI.	= 85	„
„ „	LXXV.	= 100	„
Westmoreland, „	XVIII.	= 100	„
„ „	XIX	= 90	„
„ „	XX.	= 100	„
„ „	XXI.	= 85	„
„ „	XII.	= 80	„
„ „	XIII.	= 65	„
„ „	VII.	= 45	„

True mean rainfall for the district 77 inches.

Mean of three dry years (80 per cent. of mean) 61·6 inches.

G. J. SYMONS.

136 Camden Road, N.W.

P.S.—The returns for January 1867 indicate a higher mean at the new stations than that of 82 inches herein deduced from previous months.—G. J. S.

442. What is your opinion of the quantity of rain which can be permanently reckoned upon in that district?—At the very least 77 inches.

443. (*Sir J. Thwaites.*) Are you referring to the lake district?—Yes, I am, and on this map, which I will now put in, I have marked the exact fall at each of the places (*handing in the same. See Map, Appendix* F. (1.)) You will perceive that some of the stations are underlined with a red stroke, those gauges have not been at work for so long a period as the others.

444. Are those Dr. Miller's—Portions are Dr. Miller's, which have been renewed, as you are no doubt aware, by Mr. Fletcher, but Dr. Miller's observations are almost exclusively confined to Langdale and Borrowdale, the other portions are comparatively untouched, except that we have some very old gauges in dry spots in different places round about Ulleswater—there is one by Mr. Marshall, the member for Cumberland.

445. (*Chairman.*) How long have those gauges been in operation?—The short period ones have been in operation three months. I may add that the January returns have since come in, and they indicate rather higher values than those marked upon the map, which map was prepared before the January returns came in.

446. But those figures under which you have placed the red line represent gauges which have been down for three months?—Yes.

447. And the gauges in the other parts of the district have been down for how long?—In some cases 22 years.

448. In how many cases have they been down 22 years?—The gauge at the Howe Trout Beck at Windermere has been down 22 years with a mean of 80 inches, and the Seathwaite gauge has been at work 22 years. There can be no doubt whatever about that.

449. Will you give us seriatim the numbers which are on this map, and the number of years which each gauge has been down (I assume that each number represents a gauge), commencing with number 80, which has been down 22 years?—Those numbers represent the absolute fall at those spots, and not the number of the station, that is to say, there is no reference number to the station. The rainfall is 80 inches, or whatever the number of inches are marked on the map.

450. But then, although each number represents the inches there, it also represents the gauge?—Yes, certainly.

451. The one marked 80 at Trout Beck has been down you say 22 years?—Yes, and the Seathwaite gauge, marked 140 inches, has also been down 22 years, and the Keswick gauge, marked 59 inches, has been down 22 years. I have a table which shows the number of years and the fall each year.

452. Therefore at Trout Beck, Scathwaite, and at Keswick, the gauges have been down 22 years?—Yes, and the yearly falls at all the other places are given on the large sheet, and where there are blanks there are no returns. Perhaps I might be allowed to make one remark as to the principle upon which that table has been constructed; it is this, the mean of a few years, or of a short period of observation, is no true guide to the real mean of a large number of years. They may be four or five wet years or four or five dry years, and it would not do simply to compare the mean of those years irrespective of their relation to the mean of a long period. It is consequently necessary to establish some kind of standard of reference, so that we shall know whether an observation made, we will say in the year 1845, represented an average year, whether it was a wet year or whether it was a dry year. If we have not the means of doing that we cannot reduce it to a real indication of the average, and therefore the three stations of Trout Beck, Seathwaite, and Keswick, where the long observations have been continued, were reduced to ratios or percentages, and those percentages have been multiplied into the fall in any group of years anywhere else, so as

to reduce them to their true value, consequently I get two lines of means at the foot of this table, one of those lines of means being the arithmetical means which can be taken if the other be not possible, but I should say that it is preferable to take the true mean, which is computed in the way I have described. That is the only remark which I wish to offer upon that table.

453. (*Sir J. Thwaites.*) Is that line which you have marked the gauging area of Mr. Heman's scheme ?—Yes.

454. And why is there the distinction of a red boundary ?—I believe that that is a second portion which they propose to take up, but I have nothing to do with the engineering department.

455. (*Mr. Prestwich.*) Are you able to divide the rainfall into seasons ?—They have simply taken the gross fall ; at the same time, in working out the three months last year, during which the new gauges have been established, I have reduced them to their true values by determining the ratio of the fall in those months at old established stations to the mean at those old stations.

456. Can you not give us the divisions into seasons ?—I could prepare it in that way, but I have not the materials with me at present. I should be most happy to prepare it, if desired. I may add roughly, that the percentage of the total fall which usually falls in the three months of October, November, and December is 30 per cent. of the total, or nearly one-third falls in those three months.

457. In Mr. Heman's pamphlet a table is given of the number of days on which rain falls, as computed by Mr. Beardmore ; have you prepared also similar tables ?—I have not, because I believe there is no more fallacious and no more difficult thing than to find the number of rainy days, or what is called a rainy day. That has been a source of discussion in my own periodicals for some years, and it is only during the last two years that any decision has been come to. We now always count not as a rainy day but as a day with rain, a day on which not less than $\frac{1}{100}$th of an inch falls ; it is simply in order to get some uniform standard.

458. Would not the amount of evaporation in a number of days in which rain falls be a very important consideration ?—It would, but in a district like the lakes, where the rocks are so very hard, I imagine that the water runs off very rapidly ; in fact, I know from my own personal knowledge, that it is all down into the lakes almost instantly, and consequently the evaporation from the surface of the ground, in the ordinary sense of evaporation or percolation, is almost nil. I might illustrate that by referring to the notoriously wet districts of Seathwaite and the Stye. The Stye had 224 inches of rainfall last year. I was at Borrowdale in October of last year, and I found that during the previous month of September there had been, I think, 32 inches of rain. I was close to the Stye again, and all about the valley, in the subsequent month, on the 14th of October, and the brook was entirely dry, there was not a trace of water to be seen, it had all rushed down into the Derwent Beck and escaped, just illustrating how instantaneously the water escaped, and showing that the rains of September had no effect at all.

459. There is no doubt that, with a hard rock like that in this neighbourhood, very little passes into the surface of the ground ; therefore, unless it ran off rapidly it would rather favour the evaporation from the surface, and if there was any cause to retain it on the surface to prevent its more rapid flow the evaporation would be all the greater ?—Yes.

460. And as that district is covered by thin vegetation, especially heath, would it not be extremely retentive of water, and would not it be likely to produce considerable evaporation, and yet at the same time it would be very difficult to determine the amount of evaporation, or is it possible to determine the amount of evaporation ?—I am inclined to think it is impossible, except by experience in analogous cases, and how far that may be forthcoming I do not know ; it is a question which I should like to take up, but the rainfall takes up all my time, and I have not time to go into that matter ; but my own impression and experience from travelling over the ground is that it is very soon dry. There are no doubt patches here and there in which the substratum is somewhat cup-shaped, and there the water must stand and keep it wet, but looking to the general inclination of the ground, which is very steep, I am disinclined to think that any considerable quantity can be retained.

461. Have you paid sufficient attention to that subject to form any probable idea of the relative proportion of rainfall which may be removed by evaporation, assuming the quantity there to be, as you say, 77 inches ?—I should not like to speak with equal confidence with respect to that as with respect to the rainfall ; but speaking from my general reading upon the subject, and not from any careful and accurate inquiry, my impression would be that about 10 or 11 inches would be the amount to be deducted ; but that, as I said before, I merely give just *quantum valeat.*

462. And that has often happened from a small fall ?—Yes. In the case of the Belfast waterworks I believe the decrease was found to be about 13 inches, and if you were to double that it would give us 26 inches, but the ground being entirely different I assume a very different value.

463. So that it depends upon a variety of conditions and without direct experiments it would be almost impossible to come to a direct conclusion ?—Yes, and direct experiment I believe to be almost equally impossible, except by impounding the water, that is to say, by gauging the rivers ; and those rivers are almost impossible to gauge, they come down so violently. I should like to be allowed to add a few words on the duration of droughts. With respect to droughts at Seathwaite I find that the only drought during the 10 years ending 1859 was one of 69 days, during which period there was an inch of rain. An inch of rain at Seathwaite is not very much, but it still shows that it was not an absolute drought, and there was no other drought of more than 40 days. With respect to the droughts in the upper parts of the district I have taken out the two dryest months during the whole period embraced by those tables so far as I can ascertain. I find that two droughts occurred, in March and April 1852 and in April and May 1861. There was only one station which had two months without any rain, and that return is unsupported by the returns from the nearest station, whereas it should be noticed that those droughts, and they are the only ones of any account in the district, occurred in two years remarkable for the greatest rains of all, that is to say, the years 1852 and 1861.

464. (*Mr. Harrison.*) You think that 77 inches is an average which may be relied upon ; what do you take to be the fall which might be relied upon in the driest year within your observation ?—In the driest year I should take it at something like 66 or 68 per cent. of the average fall, and the average being 77 inches, that would give about 53 inches.

465. That, of course, is the standard for the driest year ?—Yes, certainly ; but I believe as a rule engineers reckon upon the three driest years, that is to say, the mean of three successive dry years, and that gives 62 inches. I am not sure that it would ever fall as low as what I have stated ; it is just possible that it might, but certainly it is the very lowest. I may add that all through I have been guided simply by taking a perfectly safe quantity, that is to say, if a figure was 58·5, or anything under, I have always taken it at 58 inches, so as to be perfectly safe.

466. (*Chairman.*) You put not less than 77 inches for the mean rate over the whole district ?—Yes, not less than 77 inches.

467. Have you received the returns of the six gauges in the Welsh district which Mr. Bateman put in ?—Yes I have, but I should not like to express any definite opinion upon them, because we have not the same facilities for comparing them with previous years which exist in Cumberland. In the Cumberland district the gauges have been at work for very many years, and consequently a limited period, by the process which I

G. J. Symons, Esq.

14 Feb. 1867.

have described, can be reduced to represent the true average of a long period. In the absence of those long established gauges it is very difficult to do anything of the sort. I do not say that it is an impossibility, but it is a thing upon which I should rather hesitate before I entered. The only thing which is much of a guide is afforded by another table which I have put in. I do not know that it is much of a guide as to the value of them, but it shows at any rate the ratio of the year 1866 to the period of years there given. It is a very short table, simply containing the average fall at some stations. They are not in Mr. Bateman's district, with one exception, and of course they might be excepted to on that ground, but there are no long established gauges in his district, therefore we are obliged to go further afield. It will be seen from the table that the percentage of excess in 1866 was very nearly the same in Cumberland as in Wales. (*The witness delivered in the following table.*)

RAINFALL IN WALES.

Date.	Lampeter.	Rhayader.	Llanidloes.	Hawarden.
1855	32·37	—	—	21·80
1856	41·02	—	—	25·90
1857	40·00	—	—	28·10
1858	36·69	35.11	—	21·70
1859	45·82	50·72	—	30·50
1860	55·30	59·52	—	27·80
1861	43·98	40·73	—	21·82
1862	43·22	47·81	—	30·37
1863	45·38	42·72	—	23·06
1864	32·58	37·02		21·67
1865	42·39	41·48	43·33	21·96
1866	50·86	51·05	58·07	29·82
Mean	42·47	(9 years) 45·13	—	25·37

From this we find that the rainfall of 1866 exceeded the average at Lampeter by 20 per cent.
Rhayader by 13 per cent.
Hawarden by 18 per cent.
giving a mean excess of 17 per cent., closely approaching to the same excess as in the lake district.

G. J. SYMONS.

468. You have given in this table a place called Lampeter, in what part of Wales is that ?—That is in Cardiganshire.

469. And you have given a series of rainfalls for 11 years ?—Yes, 11 or 12 years.

470. And you make out there that the mean fall was 42·47 inches ?—Yes; whatever value is stated in the table I believe to be so.

471. The other place is Rhayader, for a period of nine years, and the mean fall you state to be 45·13 inches ?—Yes.

472. Then at Llanidloes you give only two years' gauging; in one year it was 43·33 inches, and in the other 58·07 inches ?—Yes, those were the values.

473. Would Hawarden, which is in Flintshire, bear any relation to Mr. Bateman's scheme ?—It is scarcely so, but at the same time it is the best thing that can be done. I should not say that you must take it as any guide as to the quantity by any means, but you may take it as a guide as to the ratio of the year, that is to say, if it was a wet year. In Mr. Bateman's district (*pointing out the same on the map*) there is no gauge within the district which will give us any guide as to whether 1866 was a wet year or a dry year, or how wet a year it was. Gauges have recently been established over this district, but only for about two years, therefore they can be no guide, consequently I am obliged to fall back upon Rhayader, which is a little below the Bangor district, and Lampeter, which is still further below, as a counterpoise, and Hawarden would be to the north-east, consequently a line drawn between the points which I now designate on the map would pass very nearly over Mr. Bateman's district, and as I said before it simply affords the best indication which can be obtained.

474. (*Mr. Prestwich.*) Those points are just upon the outskirts of Mr. Bateman's district, are they not ?—They are.

475. Would not the difference between the fall in the central area and the outskirts be relatively the same in the one district and the other ?—The difference would be the same, decidedly, but the absolute quantity of course is larger in the centre of the district.

476. (*Chairman.*) The fall in the central district is larger than when the district goes into the lower country ?—Yes. As far as Hawarden is concerned it is a dry spot, just as we have dry spots when we get a considerable distance on the further side of Penrith; it is astonishing how quickly the rainfall falls off. When you go 10 or 12 miles on the other side of Penrith you get a mean rainfall of 28 inches instead of 77 inches. So again, I believe the effect of the Snowdon range and the mountains round there is to draw down the water and leave it dry over Denbighshire, Flintshire, and that neighbourhood.

477. (*Mr. Prestwich.*) Therefore you must have gauges in the actual districts themselves to enable you to come to a conclusion ?—Yes.

478. Do you not consider that the conditions with reference to the fall of rain in those two areas, the Welsh district and the lake district, are similar ?—They are similar, except that the lake district always has very much the largest fall, very much larger than it is in Wales.

479. (*Chairman.*) If no gauges have been established in the Welsh district excepting a very short period, how can you come to a satisfactory conclusion that the rainfall in the lake district is a great deal more than the rainfall in the Welsh district ?—Because wherever we have had gauges in Wales they have been fragmentary, they have been in operation for one or two years, or perhaps for one year, or for two half years, so that they are not available to enable us to arrive at an accurate conclusion.

480. We are alluding at this moment more particularly to the district from which Mr. Bateman proposes to draw his supplies, where we understand that the gauges have only been in existence three months ?—Mr. Bateman's gauges have only been in existence three or four months.

481. In the absence of gauges in that district, except within the last three months, would it be safe to say that the rainfall in the lake district was a great deal larger than the rainfall in the Welsh district ?—It would not, as applied to Mr. Bateman's district, absolutely, but to adjoining stations; the fragments are not available for reducing to standards of returns, which is what I am referring to, because they are so very fragmentary, but so far as they go we have never, until this year, had a return of 100 inches from any part of Wales. I do not say that no such quantity can be found, but as far as analogy goes, and so far as the returns from the neighbourhood of Snowdon and other parts go, there is not any indication of it; we may not have found wet places when Mr. Bateman may have found them, but at the same time there is no evidence excepting that of a few months to show it.

482. (*Mr. Prestwich.*) Are not the meteorological conditions similar, as far as exposure to the breezes is concerned ?—No; I have had experience with regard to that for years, and therefore I may quote from a paper which appeared in some publication of the British Association, some years ago, of the relative rainfall of the two districts, when I first established about 25 gauges about Snowdon, and I there pointed out that it was a very singular thing that the Cumberland district lies exactly in the line which Mr. Henry Eaton, I think it was, had pointed out as the line along which greater part the English storms travelled, and that the centre of storms seemed to pass just over that line; and it was a question whether or not that might not amply account for the excess there. It is quite a theoretical matter, it is not a matter upon which anyone can speak positively, but at the same time it is a singular coincidence.

483. Supposing you were to classify the different

areas in England, so far as the extent of rainfall went, would you consider the lake district to be the district in which the rainfall was the largest?—Decidedly.

484. Have you a map in which you have shaded the rainfall over the different areas?—I have not, because until very recently I had not considered that it was safe to do so; such a map was published by Mr. Keith Johnstone many years ago, ten years probably, but that map was shaded on very indifferent observations in many cases, and I felt that if I were to put my name to a map I should wish it to be really trustworthy. Something of the kind I have just prepared for Mr. Stanford, and I believe it has been published, but that is not a shaded map, it shows the rainfall for the whole kingdom, and is a correct map on the whole, the amount being stated in plain figures.

485. (*Sir J. Thwaites.*) Will it be shortly published?—I have had copies sent up to me, and I believe it to be published. I think it is called Stanford's Hydrographical Map.

486. (*Mr. Harrison.*) How long a period should you consider to be absolutely necessary to have the observations extending over to enable you to form a correct judgment with regard to any particular district?—I think we require that the standard of returns should be not less than 10 or 12 years. In the absence of that it is very difficult to form any really sound opinion as to what temporary returns indicate, but by means, for instance, of the paper which I have handed in, that Welsh table, an approximation may be obtained.

487. Do not you think that by the result of three years' observation, and then a comparison during the same period with the rainfall of other districts, you could obtain a pretty accurate idea of what the average ought to be, taking of course such gauges as have been in existence, some of them at a little distance, for several years?—Yes.

488. You could by analogy obtain, could you not, a pretty close approximation to what the rainfall would be?—Yes, I should think within 5 or 10 per cent.

489. To what extent do you think that a whole year's observation would enable you in the same way to approximate?—That is rather a difficult question to answer. I found even at three of those Cumberland stations that the ratio of the year 1854 to the mean of 22 years, was 83 at one place and 103 at another, differing by 20 per cent. In fact they are the three best kept gauges we have in the kingdom, and therefore we must take it that the natural conditions vary certainly to the extent of 20 per cent. or one-fifth of the whole. You might possibly reduce it to closer limits, but I cannot say. I have never gone to work upon one year's observation without having standards all round it, close to it, and without them I do not feel safe as to what value could be placed upon them.

490. You have not had the whole of the particulars of the statement which was made by Mr. Bateman have you?—I did not hear his statement, and I have received simply the total quantity at each of the gauges in the three months, but when I came to examine the materials which really exist I found that they were such that I did not exactly see my way clearly to deducing the mean fall from them.

491. You do not think that by comparing districts of the country nearly similar in their main features, and by comparing the rainfall at the same periods in those different districts, you could from that form any approximate estimate or any reliable estimate?—Nothing like so reliable as the other way, and not an approach to it. If you take the mean of Mr. Bateman's returns, I think it was something like 18 or 19 inches. I have not the figures at hand, therefore I cannot speak positively.

492. (*Sir J. Thwaites.*) Do you know the district which Mr. Bateman proposes to take?—No, I cannot say that I know it from personal experience. I have been in the neighbourhood, but I have not gone over it in the same way as I have gone over the lake district. I know it principally from a careful study of the ordinance geological map.

493. You have stated that the lake district would give an average of something like 77 inches. Having regard to the pecular condition of the Welsh district from which Mr. Bateman proposes to take his supply, do you think that 57 inches would be near the mark as to the amount of rainfall?—The value at which I have arrived for Mr. Bateman's district is considerably lower than that.

494. But you take your gaugings at a lower point? You do not include the centre district, from which he anticipates the larger fall?—No; but the figures which I was just using I was using as gaugings for those three months, which, as I said just now, I think were 19 inches.

495. So that it would be four times that?—Yes; but I thought a simpler way would be to compare the corresponding three months in the lake district, and during the period in which Mr. Bateman had 19 inches the lake district had 30½ inches. Then if we take it as 31 : 19 : : 77 inches that gives 47. I do not say that that is a reliable way, but it is the best way that occurs to me.

496. (*Chairman.*) Might it not be quite possible that what was a very wet season in the lake district, might be a dry season in the Welsh district?—Yes, certainly, and for that reason I have prepared the table which I have just handed in, which shows that the year 1866 taken as a whole was very nearly as much in excess in the Welsh district, as it was in the Cumberland district; it was 17 per cent. in excess in the Welsh district, and 24 per cent. in excess in the lake district, which indicates a close analogy in two years.

497. (*Sir J. Thwaites.*) Mr. Bateman's reasoning was this, that having taken careful gaugings for three months they would give him an average of 76 inches, and he therefore concludes that there would be the same amount of rainfall in Wales, having regard to the conditions of the district as that which falls in the lake district; you do not concur in that view?—No, I do not. I do not see that the values which he has given, so far as I have been able to discuss them at present, support that view; they may do so, but I confess that I do not see it at present.

498. Your gaugings surrounding that district do not support it?—No, not at all; the old established gaugings in the district giving us something like 50 inches for the mean fall of the district.

499. If I understand you rightly the point at which your gauges were fixed were rather dry points in the Welsh district?—The old gauges I believe were at dry points, and therefore I think that the 50 inches which all the old observations give as the outside fall for Wales should probably be raised to 55, or something of that sort for the true fall, taking in the hilly district as well.

500. Taking the hilly district, and eliminating the district which you have gauged, would the hilly district yield a larger amount of rainfall than 55 inches?—It might do so, but whether it would or not I certainly am not competent to say.

501. Judging from the analogy of the higher lands in the lake district presenting a westerly aspect, and catching the westerly winds, would you not have similar results on the Welsh mountains to those which you have in the lake district?—Yes; but the low stations in the Welsh district do not give such a high value as the low stations in the Cumberland district, take for instance Seathwaite, that is admittedly exceptional, but still we have 140 inches per annum there at 400 feet above the sea.

502. How is that situated, is it in a gorge or not?—The Seathwaite gauge is scarcely in a gorge except that all that part of Cumberland is more or less of the nature of a gorge, but still it is a moderately wide valley, perhaps half or three quarters of a mile across.

503. Would not the moisture be carried rapidly through and deposited at a lower point?—The rain comes from the south-west along the valley, and is deposited in this part (*pointing to the map*), and is unable to get over the ridge.

504. What is the result of that gauging?—140

G. J. Symons, Esq.

14 Feb. 1867.

inches, and a little further up the valley it is 180 inches at a place called the Stye.

505. Then judging from analogy that whereas a larger quantity of rain falls in the lower district, in what you might call the dry district of the lake district, than falls in what you might designate the dry district in the Welsh area, you conclude that on the whole there is a larger fall of rain within the plain in the lake district than in the Welsh district?—Decidedly.

506. That is the process of your reasoning, and that is the result?—Yes.

507. (*Mr. Prestwich.*) I see that at Keswick the mean annual fall is given as 60 inches?—Mine comes out 58·53, as against 60.

508. What distance is Seathwaite from Keswick? Nine miles, and the rainfall at Seathwaite is about 140 inches.

509. That shows the heavy rainfall to be centred in small areas?—Just so, so far as that part is concerned; it is astonishing, as I before explained, how very rapidly the heavy falls decrease in certain directions. In other directions from Seathwaite you may go from 20 to 30 miles and keep up to the average 100 inches all the way, whereas if you go upwards from Seathwaite to Keswick you drop down to about 60 inches.

510. Is any part of the rainfall of Seathwaite due for depositing in Thirlmere lake?—I believe not; it runs into Derwentwater. The Easedale Tarn is a very wet district, which at present goes into Grasmere, I believe; but by the proposed plan it is to be conducted into Thirlmere.

511. (*Mr. Harrison.*) Can you illustrate that clearly by a reference to the figures on the map?—Yes.

512. Will you do so?—Yes, I should be very happy to do so. (*The witness described the same on the map.*)

513. (*Sir J. Thwaites.*) At the head of Haweswater you get 52 inches, do you not, and at the lower part 108 inches?—Yes.

514. Would it not be a very satisfactory experiment in the promotion of your scientific pursuits to test the actual discharge from Haweswater, calculating the amount due to the gathering area, and what would go off as the net result?—I should be delighted to do so.

515. You would deduct the absorption and evaporation, and you would then have something reliable?—Yes.

516. But of course that would depend, would it not, a good deal upon the nature of the soil?—Yes; taking the amount of rainfall into the lake and the amount running off.

517. Have you ever done that in the course of your studies in meteorology?—Unfortunately I have not the means of doing that, or else I should be very glad to see it done.

518. I presume that the principal difficulty is the expense of fitting the mode of discharge for the purpose of gauging?—The expense is the principal difficulty.

519. Do you remember if any given area, depositing its water into any lake or reservoir, has been so gauged. I mean the water that has been ultimately discharged from it?—Yes, I believe so, in several instances.

520. Can you name any?—I think that they draw from Glencorse the water supplied to Edinburgh in that way. I do not think that I can name any instances from memory, although I have repeatedly seen a list of ten or a dozen places in which such calculations have been made.

521. In cases where the area of fall has been sufficiently defined?—Yes, and where the rainfall has been gauged by one or more instruments in different parts, and the amount running off has been registered each day, and the total taken for a period.

522. Has it been free from any draught within the geological basin by means of deep wells?—That I am unable to say.

523. Because, in order to ascertain the fact, the basin must be full?—Of course it must; and I am inclined to think that all the experiments that have been made in that way have been in districts where there has been infinitely more percolation than there could be in the lake district.

524. (*Colonel Harness.*) Do you know whether any observations have been made upon the rainfall in the west of Ireland with regard to the rise and fall of the lakes?—I am aware that there have been such observations, but I have not had time to see them.

525. (*Sir J. Thwaites.*) Then the calculation that 12 inches is the mean of what is abstracted by means of absorption and evaporation is after all a theory?—To a great extent it is a theory based upon the facts which have been observed in other districts.

526. (*Mr. Harrison.*) Have you looked through the evidence given by Mr. Bateman on the 6th of February, page 5, and on the 7th of February, in the first and following pages?—Yes, I have.

527. Have you examined particularly the conclusion at which he arrives from the different statements which he has made?—Yes, I have; I find that he draws two principal conclusions. In the first instance he assumes throughout that the year 1865 was an excessively dry year, one of the driest years on record (in fact he frequently speaks of it as the driest on record), whereas really, as far as I am able to ascertain, it was about 13 per cent. below the average; and in the year 1853 it was 17 per cent. below; in 1856 it was 25 per cent. below; in 1857 it was 21 per cent. below; and in 1858 it was 19 per cent. below. The average of the last four of those years, that is to say, the four years from 1855 to 1858, was a deficiency of 26 per cent.—twice as great a deficiency as existed in 1865, simply showing that 1865 was not absolutely to be looked upon as an excessively dry year.

528. Does not Mr. Bateman refer to it as a dry year as specially applicable to Wales?—He refers to it as such on page 5; but you will observe that in answer to question 24 on page 6, he says: "The general "average of the whole of the remainder of the lake "district may be taken in an averege year at pro- "bably 70 or 80 inches, and in a year of drought, "like 1865, at 60 inches." He has just been speaking of the whole of the districts of Scotland, Wales, and Cumberland as being so strictly analogous. Then Sir Benjamin Phillips goes on to ask him, "What is that as compared with the Welsh district?" to which he replies: "The same. I do not believe that there is any "difference between the rain falling in North Wales "and the rain falling in the lakes;" making it therefore apply to the Welsh district. Then again, at the top of page 8, after saying that "We should be justified "in taking the average at something like 75 inches "of rain for the district in Wales," he goes on to say, "That was about the amount of rain in 1865, which "was the very driest year." So that he appears to consider that it does apply to Wales. One of these tables which I have produced illustrates it. The fall in the year 1865, at Rhayader, was 41½ inches; in 1864 there was a fall of 4 inches less, only 37 inches; there was the same fall as near as possible in 1863; and in 1858 there was only 35 inches, 6 inches less than there was in 1865. I do not know that it is a very material point, but it still shows that 1865 cannot be regarded as anything like the minimum for which provision should be made.

529. Looking at all those figures, which are presented in Mr. Bateman's evidence, do you think that he has calculated it too high when he takes 36 inches as that which he may safely take as the available rainfall?—If I understand 36 inches as the amount to be relied upon as the available quantity of water to be taken away from the district in a year of drought, that is to say the 36 inches which he speaks of, for he says, "I only take 36 inches out of the 48 inches," I should suppose that that means that he would have 36 inches available out of the 48 inches falling on the district in the driest year.

530. (*Mr. Prestwich.*) I do not think that that is quite the way in which he expresses himself?—It

occurs on page 1 of the second day's evidence, February the 7th.

531. I think he considered that there were 48 inches available out of the fall, but he would not take the extreme quantity which he considered available, but only 36 inches?—If there were 48 inches available it would require an addition, roughly speaking, of 10 inches for loss by evaporation and other causes, which would raise it to 58 inches.

532. (*Sir J. Thwaites.*) I think he took 12 or 13 inches for loss?—Then that would make it still more, only I did not wish to make it extreme.

533. (*Mr. Harrison.*) I think that he takes 12 inches from the 48, leaving 36 as the available rainfall for all his purposes?—That was the impression upon my mind, but at the same time I did not feel safe about it.

534. (*Mr. Prestwich.*) At page 6 of the first day, near the bottom of the page, he says, "But the general "average of the whole of the remainder of the lake "district may be taken in an average year at probably "70 or 80 inches, and in a year of drought, like 1865, "at 60 inches." There he allowed 12 inches for loss, leaving 48 inches for collection?—Yes.

535. But out of that 48 inches he only took 36 inches, allowing for the loss?—I think he is quite safe in stating 36, but I do not see how he can reckon upon the other, and partly for this reason, the mean of his returns is 19 inches for the three months of October, November, and December last year, and the mean of the corresponding period in Cumberland was $30\frac{1}{2}$, or say 31 inches. This would apparently indicate that the fall in the Welsh district was two-thirds of that in the lake district, namely 20 inches in Wales against 30 inches in Cumberland. If so, and if we apply that to the means deduced from the short period gauges in the lake district, they gave a mean of 82 inches, and two-thirds of that would be 54 inches; but I have shown that the real mean in the lake district may be taken at 77 inches, and this would give a mean for Mr. Bateman's district of 51 inches; and the mean of course for the three dry years would only come out 41 inches. I should say, from general knowledge, irrespective of the value so given, that that is below what really exists in that district.

536. You would rather draw a comparison between the one and the other from three months?—Yes, the difficulty in answering, which no doubt the Commission noticed that I felt, with respect to the Welsh district is this, that we have nothing, or scarcely anything with which to compare what we have got. At the same time what we have by no means supports what Mr. Bateman says, that there is the same fall in Wales as there is in Cumberland. I am inclined to think that it may be taken, roughly speaking, at two-thirds of the Cumberland fall.

537. Can you state what the rainfall was at Keswick in 1865?—49·18.

538. I see that Mr. Bateman gives the fall at Dolgelly, which is at the foot of the mountains in the same way as Keswick, as 57·59?—Yes, if we take the case of Dolgelly there are two guages there, one of them, which appears to be at the very low elevation of 43 feet, gives 52 inches, and the other at 500 feet gives 57 inches, making a difference of five inches between the two gauges. Perhaps I may be allowed to put in this pamphlet, which contains the rainfall in the year 1865 (*handing in the same*).

539. (*Mr. Harrison.*) I think you make out that the least rainfall in the Cumberland district, specially referred to, would be 53 inches?—That would be in one year of excessive drought.

540. But taking the average of three years you make it 62 inches?—Yes, 61 or 62.

541. Then are we to understand that comparing that with the Welsh district, you would not consider it safe to take more than two-thirds of that amount, or say 41 inches?—I consider that the observations, so far as they have gone, indicate that. At the same time, my own experience, and my own general impression would be, that rather more than that must be expected, but I do not see any weak point in the calculations which I have made; I do not know where it is if there be one. The old established gauges in the Welsh district all give a lower mean value than those in the lake district; in fact I may just point them out on this large map. We have a gauge at Bala, at the head of the lake, and we have one at Rhayader, and we have others further south, and they all give somewhere about 49 inches for the mean annual fall. If you take two-thirds of that 49 inches you get something like 33 inches for the fall in the one very dry year. But Mr. Bateman's values show that the fall in the mountains is far in excess of that which we have at those low places, and therefore that 33 inches might be raised probably to something like between 40 and 50 inches, for the higher parts are the wet parts of the district. It is just the same thing with respect to the existing Welsh stations as it is with respect to the Cumberland ones. The old Cumberland stations, with the exception of those started by Dr. Miller, gave rather low falls. When the Welsh district was regularly examined, much heavier falls were found in certain places, but in Cumberland they are found all over the district, as I have shown, right across to Shap, whereas in Wales, as far as they have been found, they are apparently more detached with dry places between them.

542. From a rather more extended consideration of those facts which Mr. Bateman has stated, taking the rainfall that you have, extending over the same period at Rhayader, Bala, and Llanidloes, and then taking into account the three months' returns which he has made, and comparing those three months' returns with the fall for the same three months at the other stations, of which you have observations extending over a long period, do you think that you could arrive at any more approximate and reliable opinion as to what would be the probable rainfall in the Welsh district?—I think that that mode of proceeding is probably the safest, and it would very likely be more correct than what I have been able to do now. To do that of course I should have to refer to the monthly returns for the past year, which I have not now with me, but I should be very happy to do so if the Commission desire it.

543. How many years have those other gauges been kept at Rhayader, Llanidloes, and Bala, and two or three other places?—That at Rhayader has been kept nine years, and that at Llanidloes has been kept two years. There are returns from Bala of a more or less fragmentary nature for about two and a half years. There is nothing else near, and indeed nothing else, as far as my memory goes at present, that will serve as a standard for comparison.

544. Then the observations for the three months are in the actual district intermediate and nearly in a line between Hawarden and Lampeter?—Yes.

545. Taking the comparative heights at which those observations have been made, and with your knowledge of the lake district of Cumberland, and the relative heights of the positions in which the gauges are kept there, do you not think that if you were to give all your mind to the study of those facts which we have, you might be able to arrive at something like a pretty approximate opinion, of course without tying yourself to it, but a pretty fair opinion as to what the probable rainfall would be?—I should be very happy to do the best I can to work it out in that way. I think that I might probably get an accurate result within 10 per cent., or something of that sort.

G. J. Symons Esq.

14 Feb. 1867.

The witness withdrew.

R. Hassard, Esq.

14 Feb. 1867.

RICHARD HASSARD, Esq., examined.

546. (*Chairman.*) You are a civil engineer, I believe?—Yes.

547. And a member of the Institute of Civil Engineers of England?—Yes.

548. You are well acquainted with hydraulic science, and have had, have you not, a great deal of experience in designing works for the water supply of towns?—Yes.

549. Will you give us the names of a few of the towns which you have supplied with water?—I constructed gravitation works for supplying the city of Londonderry, in Ireland, with pure soft water, at high pressure, on the constant system. When I was in the employment of another gentleman some years ago, Mr. Ranger, I designed works for the water supply of Southampton, Dartford, and Worthing, which were pumping schemes. I also designed for the same gentleman a large gravitation scheme in Yorkshire, which was thought a good deal of at the time, and was for supplying from the head of the river Don, at Dunford Bridge, the towns of Dewsbury, Batley, and Heckmondwicke. My professional connection with Mr. Ranger ceased after the Act was obtained, and I had nothing further to do with the works. I mention that because I believe there were some errors of construction in carrying those works out, but for them I was not in any way responsible. About six years ago I was the successful competitor in the case of the Dublin waterworks. Several engineers of repute put forward projects for the supply of that city, and amongst others there were projects put forward by Mr. Bateman and by Mr. Hawksley, both well known as waterworks engineers, but the project which I had designed and advocated, although it involved bringing water from a much greater distance than any of the other projects, and necessitated apparently a greater outlay in the first instance, received the recommendation of Mr. Hawkshaw, the Royal Commissioner, and the works are now almost completed.

550. What is the distance from which you brought the water to Dublin?—It was about 26 miles from Dublin, at a place called Roundwood, on the river Vartry. The drainage all flowed southward, and my plan was to reverse it and take it northwards to Dublin, somewhat in the same way but in a contrary direction to what is proposed in this project. The project also in another respect was somewhat similar to this one, inasmuch as it was laid out for the supply not only of Dublin, but of several places along the line of the aqueduct. I am also engineer to the Sligo Corporation waterworks, for which the sanction of Parliament is now sought to be obtained.

551. What quantity of water per head per diem do the Dublin people require?—The supply is estimated for 40 gallons per head per diem; the population is 300,000, and the estimated quantity is 12,000,000 gallons.

552. Could they get more in Dublin if they wished it?—That supply can be extended to a much larger amount, if necessary; a greater area of drainage ground can be taken in.

553. Do you find practically that in Dublin 40 gallons per head is the limit of what they require?—That is what those works were laid out for in the first instance, with the facility of extending them afterwards if the necessity arose.

554. (*Mr. Harrison.*) They are not completed yet, are they?—The works are nearly completed, but the water is not yet introduced into Dublin.

555. (*Chairman.*) The distance that you bring the water you say is 26 miles?—I think that is the distance, speaking from memory.

556. What area does the gathering ground cover?—The gathering ground covers 19 square miles, or something about 13,000 square acres.

557. Your experience appears to be very great in water engineering, and you say that your works were constructed in Dublin to supply 40 gallons per head, what quantity per head per diem should you consider necessary?—I did not construct the works; I designed the scheme. The Corporation paid me a premium for the design, and then they carried them out by their own officers, in every respect almost identical with the way in which I had projected them.

558. Is 40 gallons per head the extent of the supply to Dublin?—40 gallons is the first instalment, and it can be increased hereafter if necessary.

559. In your opinion is 40 gallons per head per diem sufficient for a large population such as that either of Dublin or London?—For Dublin probably it might be sufficient, for Dublin is a city in which there is very little trade or manufacture, speaking comparatively, and water, especially soft water, when it is introduced into any town is very largely used for all purposes of manufacture. It is found to be the case in Glasgow, Manchester, and Liverpool, and in every town in which it has been introduced. In fact in Glasgow the amount derived from the sales of water for trading and manufacturing purposes I think is nearly double, or something of that kind, the amount derived from the rates. I shall put in tables which will explain that quite clearly.

560. We have it that at Glasgow the amount supplied is 46 gallons per head per diem by Mr. Bateman's scheme?—I believe that it is generally taken at 50 gallons, there is no doubt great waste.

561. What would you consider to be a proper and sufficient quantity of water per head per diem for London?—I do not think that any project which would not eventually supply, or was not capable of supplying 50 gallons of water for each individual of the population should be entertained, and it should not only be capable of supplying 50 gallons per head to the present population, but it should also be capable of supplying 50 gallons per head of the increased population that we may reasonably expect in 20 years after the completion of the new works, the supply being increased from time to time as the demand for the water arose.

562. (*Sir B. Phillips.*) You take for the present 50 gallons per head per diem, with facilities for increasing *pro rata* with the population?—Precisely.

563. (*Sir J. Thwaites.*) You stated, did you not, that your gathering ground in Dublin was 13,000 acres?—Speaking from memory, I think that that is so.

564. What is the rainfall that is due to that area?—I can only speak from memory. I think that the net available rainfall was in that case taken at 15 inches.

565. (*Chairman.*) Can you state to the Commissioners the whole rainfall, what you take for corporation purposes, and then what is left for absorption and compensation?—I shall put in a statement of that. I am only speaking from memory, and I do not recollect the figures exactly.

566. (*Sir J. Thwaites.*) Is it a mountainous district from which you derive your supply to Dublin?—It is a hilly district; the geological formation is partly granite and partly silurian, the same as the lake district. It is a hilly district, the mean elevation being about 1,060 feet above the sea.

567. In designing your scheme for the city of Dublin, you must have carefully gone into the question of rainfall, and how much would be the net result due from that 13,000 acres?—I did so very carefully; I estimated it there at 14 inches.

568. Are you able at this moment to state to the Commissioners the actual rainfall?—I shall put it in.

569. Would it be 40 or 50 inches?—No, the rainfall was not so high as that; it is on the extreme eastern coast of Ireland, with a great area of country for the rain clouds to pass over before they reach it, and there is a great deal of elevated ground on the western coast, which intercepts more or less rain; it was between 30 and 40 inches.

570. Assuming that it was 35 inches of rainfall, you lost, did you not, 20 inches?—No; I estimated the loss

at 14 inches in that particular instance leaving 21 inches as available for supply and compensation.

571. Did not you state that the available quantity was 14 inches?—The available quantity that was taken for the mean of three dry years was 14 inches, that is for town's supply, exclusive of compensation. That was the quantity upon which the calculations were based, as far as my memory serves me.

572. Supposing the actual fall during those three years was 35 inches, and it could scarcely be less, I apprehend you lost 21 inches, if you had a remainder of 14?—No. I say that the scheme was laid out to be capable of supplying Dublin, after giving compensation in water, with a remaining depth of only 14 inches, because at the time that those works were designed there were no rain gauges in the country, or in the district which would enable us to form any reliable estimate, and therefore in order to insure the perfect working of the scheme a drainage area was secured on which 14 inches of available rainfall would supply 12,000,000 gallons daily to the inhabitants of Dublin.

573. You are not aware at this moment as to the margin beyond 14 inches?—I am not, but I can ascertain it.

574. You fixed upon 14 inches as the quantity which you thought would be derived from that area?—Yes; I fixed upon an area, which with 14 inches of available rain, would give a daily supply of 12,000,000 gallons.

575. I understand that those works are not finished, and are therefore not in operation?—They are not quite finished.

576. You do not know to this date, do you, what will be the result of those 13,000 acres?—Yes; gauges have been kept for the last six years in that locality, and I know that a much larger quantity of rain than we had reckoned upon as available (that is 14 inches) has turned out to be available for the works.

577. You mean that plus the evaporation and absorption?—Yes, much larger than the estimate.

578. What is the length of your aqueduct?—The total length of aqueduct is 26 miles.

579. Is it open cutting all the way?—No, it is not open cutting any portion of it, except a very small bit just below the reservoir, before it enters the tunnel; there is a tunnel through the ridge.

580. What is the size of the tunnel?—I did not construct it; I think it is about 5 feet square.

581. Do you know the fall?—I think it has a fall of two feet per mile, but I am not positive. I did not carry out the works; I only designed the scheme. I did not design the actual works, or make the working drawings.

582. (*Mr. Harrison.*) You were engineer, were you not, for the scheme, who deposited the plans and carried the bill through parliament for the construction of the works?—No, not so; I was the engineer who furnished certain plans to the corporation on which they prepared the parliamentary plans, and went to parliament through their own officers, to secure a scheme identical with the one I designed.

583. (*Sir John Thwaites.*) Then your plan was selected, I presume, as the result of competition, as the best plan of supplying pure water to Dublin?—Yes.

584. So far as the sections and detailed matters of that kind are concerned you are not able to give evidence?—Just so; it was the general project that I designed.

585. (*Chairman.*) How long since was it that the project for supplying the metropolis and towns in the manufacturing and midland districts and deriving its supply from the natural lakes of the north first suggested itself to you?—About three years ago.

586. What steps did you take for satisfying yourself of the feasibility of the plan?—My first step, of course, was to get the ordnance maps showing all the levels of the district. Having got the maps of that district all contoured, you have all the levels and heights of the country upon them, and the eye of anyone accustomed to study them takes in at once the whole features of the country. Having got those maps, I satisfied myself of the feasibility of the project, and I communicated the idea to Mr. Hemans.

587. You must have done more, I apprehend, than getting the levels?—Yes, that was the first step that I took.

588. In order to satisfy yourself of the feasibility of the plan you must have gone into the question of the rainfall?—Yes, and I visited the locality as well. The first step was to procure maps showing the elevations of the locality; the rainfall was notorious; and I then visited the locality and projected the scheme.

589. You communicated it to Mr. Hemans, and since that you have worked the plan out together?—Yes; Bala Lake has since been incorporated in the project in order to replace water which might be advantageously sold to the manufacturing towns of the north.

590. (*Sir J. Thwaites.*) That is to say your tunnel would be nearer to some large towns, and you would supply those towns more readily than by taking the water direct from Bala?—For instance at Liverpool, which is very much in want of water, and the towns adjacent, if a quantity of water—we will say for the sake of example 50,000,000 gallons a day—were sold to that district, I should replace that quantity with 50,000,000 gallons of water taken from Bala, and having made up the deficiency I should carry on the 250,000,000 gallons to London; in fact, instead of supplying Liverpool from Bala, I should supply Liverpool and the adjacent district from our aqueduct, and carry the Bala water on to London.

591. You would compensate for the abstraction by taking that quantity from Bala?—Yes.

592. (*Sir B. Phillips.*) What is the distance from your aqueduct to Bala?—It is about 65 miles, I think. It may be 70 miles probably.

593. According to the map on the wall the nearest large towns to Bala would be the potteries?—The potteries would be very near the point where the Bala water would come; those towns are very nearly at the point at which the water from Bala would be brought in. The water from Bala would be at an elevation of probably 70 or 80 feet higher than the water in the main aqueduct, and it would be a very proper course of proceeding then to take the residue of the Bala water on, if necessary, for the supply of Wolverhampton, Birmingham, and that locality.

594. If by your scheme you propose to supply water from Bala would you run first to the towns in the potteries, and then to Congleton, Leek, Macclesfield, Stockport, Manchester, and so forth?—The water would flow in the other direction running southward.

595. (*Chairman.*) You would bring the water from the Lake district and supply the towns on the route between the Lake district and Stoke, and the water which you so abstract from your system between the Lake district and Stoke you would replace from the Bala district?—Yes, we should make it up from Bala.

596. (*Sir J. Thwaites.*) That would be 80 feet higher than the other aqueduct?—Yes, than the main aqueduct.

597. And, as I understand you, that scheme would be 70 miles in length?—Yes, about 70 miles in length.

598. And that would give you very little over a foot of fall?—About a foot of fall per mile.

599. Do you think that sufficient?—Yes, quite so.

600. (*Chairman.*) What advantage do you anticipate from this method of dealing with the district, namely, having an additional supply as it were from Bala?—There would be one point of great advantage, for instance: if I were constructing that scheme, I should make a reservoir at the point of junction of the Bala conduit at Stoke capable of holding about 21 days' supply; the regulating reservoir near London would hold 15 days' supply, making 36 days, and the yield from the Bala district for that period would be equal to about 7 days in addition, making a total storage or reserve equivalent to 43 days' supply.

601. You use the word "if." Is not the supplying of water from Bala in the manner you have described

R. Hassard, Esq.

14 Feb. 1867.

a part of your scheme?—It is an adjunct of the scheme.

602. Then it is not part of the scheme?—It is part of the scheme for supplying London, and the manufacturing towns in the provinces, from the Lakes in England and Wales.

603. (*Sir J. Thwaites.*) Will you first give us a description of your scheme proper, and then deal with this exceptional supply?—The main project is for bringing water to London from the Lakes of Cumberland and Westmoreland.

604. (*Chairman.*) May we take this to be your project, that if you merely brought the water from the Lake district to London you would not make use of the water from the Bala district, but that if you parted with any water between the Lake district and London to any of the places on the road, such as Liverpool, Manchester, Stockport, or Macclesfield, you would then consider it necessary to carry out the Bala project?—That is what I intended to convey.

605. (*Sir J. Thwaites.*) You state that after procuring the plans and examining generally the character of the district, you walked it?—Yes.

606. And finding the rainfall notorious, you designed your scheme?—Yes.

607. Finding the average of the rainfall to be 77 inches, what do you anticipate will be at your disposal when it finds its way to your reservoirs?—I take the returns at other places for the three driest years in succession. The three years 1853, 1854, and 1855 were consecutive years of very great drought; the quantity of water which fell in those years at the Rivington reservoirs, for supplying Liverpool, was 87 per cent. of the mean rainfall of 17 years. On the drainage ground of Loch Katrine, during the three years 1855, 1856, and 1857, which were also dry years, although not quite so dry as the previous years, the rain which fell on the district was 83 per cent. of the true mean rainfall of 11 years' observations. They were not the same three years, because the observations for those same three years were not obtainable, but I have given 1855, 1856, and 1857, which were also very dry years, and I say that during that period the rain which fell at Loch Katrine was 83 per cent. of the true mean rainfall of 11 years.

608. Do you mean that 83 per cent. was reservoired?—No, but that the mean rainfall of three consecutive dry years was at Liverpool 87 and at Loch Katrine 83 per cent. of the true mean annual rain.

609. Then there was a loss of 13 per cent.?—The amount of rain which fell was less than the mean average rain by 13 per cent. in the one case, and by 17 per cent. in the other.

610. Taking a dry year, I presume the abstraction by absorption would be greater in a dry year than in a wet year?—The loss is always greater in dry years.

611. Therefore this average would be, in your judgment, fair?—Yes, I take it at 83 per cent. as the lowest.

612. Did you apply that average to the district from which you propose to take your supply?—Yes, and that gives the result of 63·91 inches, or say 64 inches, of rain as the mean of three consecutive dry years.

613. (*Chairman.*) When you speak of dry years you have given us three dry years, 1853, 1854, and 1855, at Liverpool, and you have given us 1855, 1856, and 1857 at Glasgow?—Yes, which were also very dry years, but the returns at Loch Katrine for the years 1853, 1854, and 1855 were not published, and I am not aware what they were.

614. Even supposing they had been published, it would be quite possible, would it not, for 1853, 1854, and 1855 to have been exceedingly dry years at Liverpool, and by no means dry years at Glasgow?—They were notoriously dry years on the whole west coast of Britain.

615. (*Colonel Harness.*) Do you mean that the rainfall in those years was 83 per cent. of the mean of the average of the years which you have mentioned, or do you mean that 83 per cent. of that average was stored?—No; in the first case, at Rivington, the rainfall for those three consecutive dry years was 87 per cent. of the mean average rain.

616. (*Sir J. Thwaites.*) My question was whether the 87 per cent. was 87 per cent. of the rainfall due from the gathering area for the Liverpool supply in 1853, 1854, and 1855; that is to say, whether they actually caught 87 per cent. of the whole of the rainfall which was stored and found its way into the reservoir?—No.

617. Will you just explain what you do mean?—The mean rainfall at Liverpool for 17 years ending 1865 was 45·70 inches. The rainfall of the three dry years 1853, 1854, and 1855 was as follows: In 1853 the rainfall was 37·25 inches; in 1854 it was 43·36 inches; and in 1855 it was 39·12 inches; and the mean of those three dry years was 39·91 inches, which, as I have stated before, is 87 per cent. of the mean of 17 years.

618. My point is this: I want to know whether, from your observation of the rainfall of the area supplying Liverpool, you can state what percentage of that rainfall finds its way into the reservoirs?—I cannot tell you for any former year, but I can give it you for the years 1861, 1862, 1863, 1864, and 1865 at Liverpool. In the year 1861 the rainfall, as measured by the gauges, was 46·38 inches; the loss was the difference between this and 35·77 inches, being 10·61; that is to say, the loss out of 46·38 inches was 10·61 inches. In the year 1862 the loss out of 48·51 inches of rainfall was 8·43 inches. In the year 1863, out of 51·01 inches of rain, there were 10·29 inches lost. In the year 1864, out of 39·03 inches of rain, there were 11·18 inches lost; and in the year 1865, out of 34·80 inches of rain, there were 11·45 inches lost. That gives us for those five years a mean annual loss of 10·39 inches.

619. Is that the result of gauging the water as it passed into the reservoir?—I presume so. I am quoting from a pamphlet published by Mr. Duncan, the engineer of the Liverpool waterworks, on the future water supply of that town.

620. (*Chairman.*) Are we to understand that those calculations which you have now given in are what you have taken from a pamphlet published by Mr. Duncan on the water supply of Liverpool?—Yes. The mean loss, as I stated before, appears to have been 10·39 inches.

621. (*Sir J. Thwaites.*) Can you tell us whether the gauging was made at the entrance into the reservoir or at the place where the water is discharged?—I cannot tell whether it is above or below.

622. Because between those two points there would be the evaporation, would there not, which is due to the surface of the reservoir itself?—Yes.

623. And which is considerable?—Yes, amounting probably to 27 or 28 inches; but then it must be remembered that the reservoir itself forms a very small area as compared with the area of the drainage. At Manchester, I think, Mr. Bateman gave it in evidence that the average loss was 13 inches.

624. (*Chairman.*) You have stated that this scheme suggested itself to your mind some three years ago, that you have walked over the district, that you have compared the levels throughout, and that you have taken the rainfall of that district, that you have made calculations as to what amount of water that would give you, and that you propose to take it in the first place to London, and if necessary, to replace from Lake Bala the water which you might furnish to the towns on the road which might require it. Will you have the goodness, beginning at the top of the map, to describe shortly how you propose to bring the water to London, and the various points of detail which Mr. Hemans left you to give us?—We propose, as Mr. Hemans stated yesterday, collecting additional water in Haweswater by conduits constructed along the hill sides, intercepting the streams in a westerly direction from the River Lowther, at a point called Cooper's Green, taking in Swindale Beck, and Naddle Beck, and in a northerly direction from a stream called Heltondale Beck, taking in Gill Beck, and Hows Beck on the way, and then we convert Haweswater into a large storage

reservoir. The only part of the locality where there is any peat is in the Swindale district draining into the river Lowther, and we therefore propose to apply the water of Haweswater as the least excellent of the whole, for the purposes of compensation.

625. The gathering ground of the supply of Haweswater appears, does it not, from the figures upon that map to be some 38 square miles?—Yes, the available natural drainage area is probably not more than half that, but that would be the available area when those catchwater drains are made.

626. How much of that district is peat?—A very small portion.

627. Can you give us the acreage?—I should think $\frac{1}{20}$th part; $\frac{1}{20}$th part would probably be, in round numbers, two square miles, and that would be 1,280 acres, and the peat is only in small patches here and there.

628. (*Sir J. Thwaites.*) Are you sure that there is no peat on the west side of the river?—There is a little peat here (*pointing to the map*), which occasionally colours the river Lowther.

629. There is peat, is there not, on the other side of Bampton Common. There is a very small quantity of peat; there is heath, as there is on all the Surrey hills, and the Bagshot Sands are covered with heath; but there are no mosses that colour the water to any extent.

630. You propose, do you not, to increase the depth of Haweswater 42 feet?—Yes.

631. And you propose to run a dam across at the lower end?—Yes, across the outlet of the lake, which is a very favourable spot for constructing it.

632. On that side where the figure 38 is have you not a very high mountain?—Yes.

633. And on the other side you have a series of small farms?—Yes, immediately adjacent to the lake itself, but it is a very narrow strip indeed; there are high mountains coming in on that side.

634. Are there not houses all the way up to the town of Mardale?—There are some few houses; I have another map showing that. The blue line will show the margin of the lake, when it is raised 42 feet.

635. But are there not houses all the way up?—There are some houses; for instance, there is the Parsonage, but the only other good house is the farmhouse called Measand Hall.

636. Will not the Dun Cow inn be covered?—No, you will see that the hotel is higher up.

637. The whole of this area covered blue will be covered, will it not?—Yes, that area amounts to 370 acres which will be submerged.

638. Do you know the width of the cultivated ground on the small farms there?—About 10 chains, or 220 yards.

639. Then I presume your scheme contemplates the purchase of all the interests affected within the blue line?—Yes.

640. Have you made an estimate of the cost?—Yes, I have. You may recollect the little romantic church there, and it will give you an idea of how high the water would come when I tell you that its surface would be about 8 feet below the entrance of that, Mardale church.

641. On the south-eastern side you simply encroach on the forest?—Yes.

642. The compensation would be slight on the south side, but on the western side it would involve, would it not, the purchase of all the houses and land affected by the lake, including 370 acres?—Yes, of the whole of them.

643. What is your estimate for that?—I have estimated 370 acres of mountain land at 75*l.* an acre, and then I have for rebuilding houses put down 6,000*l.*, which I make up in this way: 1,000*l.* for rebuilding Measand Hall, 1,000*l.* for rebuilding the Parsonage, and for five cottages and small farmhouses I have put down 200*l.* each, amounting altogether to 3,000*l.*, and I have then 3,000*l.* to spare.

644. When you speak of rebuilding, you take away their land, and you take the houses up into the mountain; it would be a question of destruction, would it not, rather than of rebuilding?—You would have to pay for the houses in one shape or another, either by rebuilding or by paying the money.

645. Are you not taking the land on which the houses are built?—Yes, certainly.

646. What is the whole amount of your estimate for the Haweswater reservoir?—The total is 73,500*l.*

647. Does that include your dam at the lower end?—Yes, it includes everything. There are 127,500 cubic yards in that dam; that I take at 2*s.* per cubic yard to cover puddling, pitching, and soiling, &c., which is a high price, and that amounts to 12,750*l.*

648. (*Chairman.*) Could you furnish us with a statement first of all of the general result, and then of the mode by which you have arrived at that general result, together with the details?—Yes, I shall be happy to do so.

649. (*Sir J. Thwaites.*) I understand that by means of this dam increasing the height of the water 42 feet, you propose to store a sufficient quantity of water to compensate the river Lowther?—Not only to compensate the river Lowther, but also to act as compensation on the river Eamont, in fact, to act as compensation for the whole of the eastern portion of the scheme. The Thirlmere compensation would be separate.

650. Would the discharge be continuous under your plan?—Yes.

651. Then in dry weather you would have, would you not, a larger flow of water down the Lowther than there is at the present moment?—Yes, very much more; probably double in volume.

652. Though you deprive them of the benefits of the storm floods you would give them a daily average beyond that which they have now?—We deprive them of the flood water, but in lieu of that we double their summer supply.

653. You are probably aware that they are making arrangements in that river for the salmon to pass up?—The only arrangement that I am aware of is that at a place called the Eel Coop, on Haweswater Beck, half a mile below Haweswater. About 18 months ago they were erecting a salmon stair, but up to that time no salmon had gone into Haweswater.

654. How do you propose to deal with that question—would not your dam effectually stop the progress of that work?—It would of course prevent the salmon getting up; but with a lake, equally well with an artificial reservoir, there might be means adopted to allow the salmon to get into the lake by a long salmon stair, but at the same time I do not believe that the salmon would go into the lake, because there is no spawning ground adjacent; there are cliffs all round it, and no streams with gravel beds into which the salmon would go for the purpose of spawning, so that, as far as salmon breeding goes, I do not see that the raising of the level of that lake would at all affect the question.

655. (*Chairman.*) Looking at the southern point of Haweswater, I see marked upon that map what appear to be several streams which run into that lake; do you apprehend that those streams would not become spawning ground?—They are quite precipitous—a mere succession of water-falls.

656. (*Sir J. Thwaites.*) You also propose to raise Thirlmere, do you not, to the height of 64 feet beyond its present level?—Yes.

657. And you propose to do that also by means of a dam at the lower end?—Yes, there is a very narrow gorge there.

658. On the right of Thirlmere, between Helvellyn and the Fells is the road to Keswick and Ambleside?—Yes, it runs close to the lake, as you will see by this map (*producing the same*). The existing road will be submerged for a considerable distance. It runs from the high ground down to the level of the lake, and then runs up at the other end, and in lieu of that we propose making a level road along the contour line from one point to the other. The hillside has a slope of about $3\frac{1}{2}$ to 1, or 3 to 1.

R. Hassard, Esq.

14 Feb. 1867.

659. (*Chairman.*) Is the present road a hilly road?—Very hilly.

660. (*Sir J. Thwaites.*) The road along the lake is level?—Yes.

661. Then the new road would have rather a serious inclination would it not?—No, it would be a dead level from one end to the other.

662. (*Mr. Harrison.*) You would have to cut the road and conduct it along the steep side of the hill?—Yes, it would be a bench on one side, and a wall on the other.

663. (*Sir. J. Thwaites.*) What acreage of land do you cover by the elevation of the water?—400 acres.

664. What is the length of Thirlmere lake?—Nearly four miles.

665. (*Chairman.*) Do you mean that the lake is four miles, or the ground which you will occupy?—The ground which will be submerged. The lake is about $2\frac{1}{2}$ miles at present, but with the ground which we propose to cover with water it would be about $3\frac{3}{4}$ miles in length, and there would be 400 acres of land submerged.

666. (*Sir J. Thwaites.*) You have made, I presume, an estimate of the property which you destroy all along the border of Thirlmere?—Yes, the total estimate for that reservoir is 83,000*l.*

667. Does that include the dam, and compensation for land and houses?—Yes, it includes everything.

668. How many acres of land do you take?—Four hundred acres.

669. At what rate?—At 75*l.* per acre, which amounts to 30,000*l.*, then I have put down for rebuilding houses 8,000*l.*

670. Some of this land is very valuable is it not?—Some of it is valuable, but a great deal is very poor indeed. You may see from the map that the nature of the land coming down on the eastern side is bare rock.

671. But when you approach the lake, you get some very valuable meadows?—Yes, but the average value would not be more than 75*l.* per acre, which I put it at.

672. How many houses do you remove?—There is one house called Armboth, which is a very good farmhouse, then there is a small parsonage near the church, and there are 18 cottages and small farmhouses, which are of a very ordinary description. As to Armboth, I have allowed 1,500*l.* for rebuilding it. The total amount for that reservoir is 83,000*l.*

673. Now going on to Ulleswater, I think that for reasons given by Mr. Hemans, you only propose to raise it five feet?—Virtually it would be raised only five feet above its mean winter level, or above the ordinary level of the autumn, but two feet above the extreme winter level.

674. I understood Mr. Hemans to say that it would be practically 5 feet above the average winter level?—That is so.

675. Are you aware that on the banks of this lake there is very valuable property?—There is some very valuable property there.

676. Would the increased height of the water submerge any part of that property?—A very small portion indeed.

677. Can you describe the portion which would be submerged?—Yes, I have a map which will show that. The points on the map which you see coloured represent the points where the existing roads will be submerged and new roads will be made. A great deal is bare rock. There is very valuable property at the Patterdale end, but that we shall not submerge.

678. What do you mean by colouring it green?—This stream, named Grizedale Beck, which comes down from the upper part of the valley, now receives the drainage of this portion which is coloured green, and those are meadows which are submerged in winter, probably for two-thirds of their extent. We propose to divert this stream by a watercourse in the position described on the map, taking Goldrill Beck also, and constructing a small catchwater drain on the eastern side of the valley, which will intercept all the water which now flows into that lake at its southern extremity. We then put a bank across the top of Ulleswater, a small bank, probably about 7 feet or 7 feet 6 inches in height, which will keep the portion coloured green secure from the effect of floods from the water backing up from the lake. Very near to the south end of the lake you will observe our eduction aqueduct towards London, the first portion of which is open, and into that would drain the rainfall which would be precipitated on that portion of land which is coloured green.

679. In future you would prevent that which now occurs, namely, the flooding of the portion coloured green?—Yes.

680. (*Mr. Harrison.*) Do you put your catchwater drains at such an elevation as would carry that water to the highest level of the lake?—Yes.

681. (*Sir J. Thwaites.*) At what point do you intercept the washings from the lead mine?—We intercept the washings from the lead mine at Glenridding, at the lead mine itself, and we propose carrying it by a line of iron pipes until it would be discharged into the River Eamont beyond Ulleswater. The cost altogether for intercepting that mining drainage I have put down as at 35,000*l.*

682. (*Chairman.*) What powers will you have for taking this water from that spot into the river Eamont; would not those who live on the river Eamont object to having this water, which you consider too bad to go into the lake, being sent into the river Eamont?—It first goes into the lake, and then into the river Eamont, at present.

683. You would take it by a more direct course, and it would be in a more polluted state when it got to the river Eamont?—No, it would be in precisely the same condition as when it left the crushing mills.

684. When it got to Ulleswater, by your plan, it would be much more diluted than it is at present?—The carbonate of lime, for it is not lead, is now precipitated in the lake all round the mouth of Glenridding Beck, which is the stream coming down from the lead works.

685. Are we to understand you to say that the water, when it reaches the river Eamont, would not be more polluted by your method than after it left the lake, as at present; it would surely be more mixed?—Yes, I should think it would; but it must go somewhere, and the quantity of water which it would be mixed with in the river Eamont would be very large indeed.

686. If, as at present, the people on the river Eamont can tolerate this water, bad as it may be, because it has to pass through Ulleswater, and in its course through the lake is mixed with a great body of water, might it not happen that when they received the water by your method it would be in a very much worse condition, and so injure them very materially?—It would be diluted with such a large quantity of water that I think it would be scarcely perceptible.

687. If I understand your plan rightly, that water would not be diluted at all till it reached the river Eamont?—It would be diluted by a very large quantity of compensation water.

688. You state that the river Eamont would be compensated, but it would reach the river Eamont by your plan minus the dilution of the whole of the lake Ulleswater?—Yes, certainly that is the case, no doubt.

689. (*Sir J. Thwaites.*) When it is discharged at the top of the lake it gets into a comparative state of rest and precipitates the polluting matter, but if you carry it down this channel, of course from the flow in the pipe it would not precipitate at all?—It would be delivered into the river Eamont in a more concentrated state.

690. (*Chairman.*) When the water reaches the river Eamont, although it might be imperceptibly impregnated or mixed with lead now, it would be perceptibly so by your scheme?—The water was very carefully tested for lead, but not the slightest trace of lead could be found in it. The colouring matter is carbonate of lime, and not lead.

691. (*Sir J. Thwaites.*) That would affect the fish, would it not?—I saw a man standing and wading in the lake up to his knees at the mouth of that burn, and I said to the boatman, "Is it possible that the man is fishing; surely no fish can live there?" but he said that it was one of the very best places for trout in the whole lake, so that as far as the fish were concerned it did not appear to affect them.

692. This dam in the upper part of the lake is to prevent, is it not, the water which you raise flowing over that land coloured green?—Yes.

693. You will have to take some property on the north-west side of the lake; have you formed an estimate of the expense of that?—I have.

694. Apart from your structural works?—Yes.

695. Can you give us that estimate?—Yes. The total estimate for that, with damage and compensation, is 100,000*l.*; the land, works, and eduction apparatus would be 78,080*l.* The land submerged would be 76 acres, a part of it valuable land, and a part of it being bare rock and mountain.

696. In this case you would have to divert the road?—Yes.

697. That is mere forest, and it would be no very serious expense there?—No, it would not, until we got down to a place called Hallsteads.

698. Then I understand that for compensation for houses taken and for lands submerged, your estimate is 100,000*l.*?—100,000*l.* is the whole, including everything.

699. (*Mr. Harrison.*) You stated 70,000*l.* for the dam, did you not?—The land I have estimated for at 80*l.* per acre; there are four miles of altering roads, such as are shown here, which I take at 2,500*l.* per mile. There is an embankment, which is a very small thing, at the lower end, at Pooley Bridge, which would be a weir, and it would cost 2,000*l.*; and eduction pipes and valves, the eduction apparatus for drawing off the water for the supply of London, I take at 60,000*l.*, making a total of 75,080*l.*; and to that I add the difference between 75,080*l.* and 100,000*l.* for any additional compensation that may arise.

700. Can you state the height to which the water would be raised by the winter floods, or floods at any time?—By the winter floods now it is raised, from the marks which were pointed out to me, to a height of 483 feet above the Ordnance datum.

701. Can you state how high it would be raised beyond the height of your 5 feet by a fair average flood. You propose to raise it 5 feet above the winter average, that would give you 5 feet increase, what height beyond that will the floods swell it?—From the marks which were pointed out to me an extraordinary flood would rise 3 feet above that.

702. That would be 8 feet above the winter average?—No; 3 feet above the winter average.

703. Then your 5 feet above the winter average would take it 2 feet above the present highest level?—Yes. I was asked a question with relation to Mr. Marshall's house at Patterdale. The level of the ground at his hall-door is about 67 feet above the ordinary winter floods; with the raised lake it would be 65 feet above; his grounds wouldnot be touched at all.

704. (*Chairman.*) That is with regard to the three reservoirs which are to be the source of your supply for London?—Yes, London is intended to be supplied from both Thirlmere and Ulleswater, and very probably some small portion of the supply might be derived from Haweswater also.

705. Will you now state to us how you propose to supply Thirlmere and Ulleswater; because, if I gathered rightly from what Mr. Hemans stated yesterday, you first of all gather the water in the Haweswater district, then you take it from there and put it into Ulleswater?—Only the residue of it.

706. Having, first of all, made the reservoir, and filled Haweswater with water, will you state what you do with that water?—A certain fixed quantity, which has been estimated as equal to 9 inches of rain over the district, would be drawn off from the north end of Haweswater, and passed down the stream daily throughout the year in equal quantities. That is for compensation, to be passed down the river Lowther to a point about a mile below Lowther Castle, and there a gauge weir would be fixed, and a certain quantity passed down the remainder of the river Lowther till it joins the river Eamont below Brougham Hall.

707. The gauge weir, you say, would be fixed below Lowther Castle; would that gauge weir prevent fish from coming up?—No, it would be a very low affair, probably not more than 4 or 5 feet in height, and an ordinary fish stair might be applied. The river Lowther would then carry off each day not only the quantity of compensation water which was due from Haweswater, but it would also have to carry off the flood water which would be due to the area lying below those catchwater drains and the eastern side of the watershed, and that quantity of flood water might of itself at times very much exceed the quantity of water which would be due to the compensation in the river below, and therefore all, except the portion that might be fixed on as compensation, would be carried round by a conduit to Pooley Bridge, where a further quantity, such as might be fixed upon as compensation, would be delivered into the river Eamont and passed down it as compensation water, and the residue, if any, would be passed into Ulleswater.

708. (*Mr. Harrison.*) The lower level where you propose to put the weir is still above the level of Ulleswater, is it not?—Yes, the conduit from the river Lowther to Pooley Bridge would have a fall of 2 feet per mile from one point to the other.

709. (*Chairman.*) That is the mode of carrying the water from that district into Ulleswater?—Yes, that is the mode of dealing with Haweswater and its drainage area.

710. And compensating by the means which you describe the river Lowther and the river Eamont?—The water of the river Lowther is of excellent quality, still, being the least pure of the district it is proposed to use it for compensation and apply the purer water for the supply of London.

711. Will you now describe what you do at Thirlmere?—Thirlmere Lake has naturally a small drainage area. It is admirably suited for converting into an immense reservoir, but the area of land naturally draining into it is small, therefore it is necessary to bring water to it from other localities, and in order to effect that catch-water drains are projected towards the Borrowdale side, as indicated on the map. Those catch-water drains are all on the western side, at the foot of the table land which slopes towards Borrowdale. From below the catch-water drains, down to the Watendlath River into Borrowdale, the ground is very precipitous, but those catch-water drains are upon the table land at the upper side of the cliffs, and they would carry round into Thirlmere the waters of Cold Barrow Fell, and Bleaberry Fell. All those catch-water drains, with the exception of the one from the river Lowther to Ulleswater, are laid out with a fall of either eight or 10 feet in the mile, and they are open cuttings following the contour line, or nearly following the contour line of the district.

712. Have you prepared any sections of your works?—Yes, I have sections of all the works; for instance, here is a section (*producing the same*) showing the mode of construction, also of those catch-water drains. The probability is that many of them will not require puddling, as indicated there on the section, but they are all estimated as if they will; there will be a stone facing with a clay backing. Here is also a map (*producing the same*) showing the way in which they were projected from the contours; for instance, one thin line represents an elevation of 900 feet, another represents an elevation of 800 feet. The level of the catch-water drain at that point is 855 feet, the 850 feet being nearly equi-distant between the two contours. On the northern side of Thirlmere it is intended to construct a catch-water drain of precisely similar construction to what I have just shown, running along the hill sides, and following the contour with the

R. Hassard, Esq.

14 Feb. 1867.

exception of a point where a bit of tunnel would be necessary (the tunnel being a mile in length), delivering into Thirlmere at its north-eastern extremity. That catchwater drain would intercept the waters of Barrow Beck, Trout Beck, and Mosedale Beck, and also the water flowing from Matterdale Common and the hills called the High Fells. Then eventually, when the demand amounts to 250,000,000 gallons per day, it might be necessary to construct another reservoir, for which there is an admirable site, a purely artificial reservoir below Thirlmere, for the purposes of compensation. But in the first instance that would not be necessary at all, as both the compensation water and the water for the towns' supply keeping up Ulleswater could be drawn off from Thirlmere. The compensation water would be for the supply of some mills and pencil factories and bobbin mills, which are situated on the river Greta, above Keswick. Then having got the water into Thirlmere, we construct an open conduit for some portion of the distance, running northwards, and from that into Ulleswater there would require to be a tunnel, and that tunnel would be eight miles in length, but the extreme depth of the shafts would not exceed 400 feet, and it only becomes a question of additional shafts. Except as regards the increased length, that would be quite similar to the tunnel which has just been constructed for the Dublin waterworks. (*The witness produced and explained a section of the tunnel.*) It is 12 feet high and 12 feet wide, and falls 2 feet in a mile.

713. (*Sir J. Thwaites.*) Is that slate or rock?—It is clay slate in that portion of the district. In one spot near the Ulleswater end of it the old red sandstone appears for some very short length.

714. You will line the whole of this of course?—Yes, with the stone excavated in the construction of the tunnel itself. I constructed a very difficult tunnel in Ireland for Mr. Hemans in that way. It was through the same rock, and we lined it entirely with the excavated material.

715. (*Chairman.*) What is the total distance?—The total length is 8 miles of tunnel, over the whole length of which shafts can be sunk.

716. The extreme depth at any one point is 400 feet?—The maximum depth is 400 feet.

717. (*Mr. Harrison.*) You would not propose to put down the same number of shafts that you show in the section, would you?—We should probably put down more shafts, but the Kirkstone Pass tunnel is the key of the whole work, and there would not be any necessity for having this tunnel completed before that one was finished—it becomes a mere question of time. The question of the time of completion is, of course, regulated by the number of shafts; if it was to be done in two years a larger number of shafts would be necessary. We have put them down at three to the mile, with which number it could easily be completed in the time that would be necessary for the construction of the Kirkstone Pass tunnel.

718. (*Sir J. Thwaites.*) Have you made a calculation as to the cost for severance of land, where you carry your open aqueduct?—It is included in the cost of the catchwater drains themselves.

719. (*Chairman.*) Will the details appear in the statement which you have put in?—I shall hand in all the details.

720. (*Sir J. Thwaites.*) I presume that for agricultural purposes you have bridges over those aqueducts?—The occupation works were taken, I think, at 250*l.* a mile, for bridges across the aqueduct. The district is mostly sheep farms. Those catchwater drains are proposed to be fenced, and that is included in the estimate.

721. (*Chairman.*) When you talk of fencing, what descripton of fence do you propose to put up along those catchment drains?—The ordinary fences of that country, which are dry stone walls.

722. About what height?—About 4 feet 6 inches in height.

723. Do you think that a 4 feet 6 inch wall would keep those mountain sheep within bounds?—I do not think that the sheep would do any harm to the water.

724. I do not know whether the Cumberland sheep are like the Highland sheep, but no 4 feet 6 wall would keep Highland sheep within bounds?—There are not many sheep in the locality. What agricultural produce there is is sheep, but it is so bare that really there are not many sheep over the greater portion of the district.

725. But the other drains which you propose to preserve by fencing would, I conclude, be fenced against something which might be expected to happen?—I estimate for fencing, but it scarcely need have been considered.

726. (*Sir J. Thwaites.*) The sheep would not jump into the water, I presume?—No; I do not think that the quality of the water will be affected one way or the other.

727. (*Chairman.*) The fences would be dry stone dykes, I presume?—Yes, dry stone dykes.

728. Might you not save yourself the expense of putting them up?—I do not myself think that they will be required, although I have estimated for them.

729. You propose to get to Ulleswater by a tunnel, which will be eight miles long?—Yes.

730. Now will you take us on further until you get to the southern point of the lake?—From the southern point of the lake the water is proposed to be drawn off for the use of London, and from that point to Stockport, which is a distance of 110 miles, we have the sections of the course of the aqueduct carefully prepared, and shall be happy to submit them to the Commission. As soon as you get out of Westmoreland, and a short distance south of Ambleside, the whole of Lancashire is contoured to elevations of 25 feet, and that enables sections as nearly approximate as possible to what would actually occur in practice to be plotted, and there can be no essential difference between the sections which we have prepared and the sections which would be the sections of the works actually constructed.

731. (*Sir J. Thwaites.*) Your main line of aqueduct to the metropolis would commence at the upper end of Ulleswater Lake?—Yes, at the south end.

732. And you will be there in tunnel very rapidly?—There is about two miles of open cutting, and then we go by tunnel under Kirkstone Pass, coming out above Ambleside.

733. (*Chairman.*) Will you describe the portion of the ground from Ulleswater to Ambleside?—From Ulleswater to Ambleside, for the first 2 miles, the aqueduct is open cutting; then we get into tunnel, all of which, except $1\frac{3}{4}$ mile in the central portion, is a comparatively shallow tunnel. The total length of tunnel is 6 miles. Then having left that tunnel, from Ambleside onwards, we get into open ground, with occasional spurs of hills, through which we tunnel. Part of that would be covered aqueduct and part of it open. I shall produce sections showing the mode of construction. We cross, then, one or two streams running down, which are crossed by syphon pipes 8 feet in diameter, of the same material as was shown yesterday by Mr. Hemans and lined with Portland cement. There is very great economy in using those large pipes, which I shall explain by-and-bye.

734. What is the depression of the pipe at Bridge Lane?—There it would be about 140 feet. From Bridge Lane onwards the same mode of construction is followed, partly open aqueduct and partly tunnel, until we get to Staveley, where there is another depression of about 150 feet. There are some watercourses, and we estimate for bridges over all those; and from that onwards the same mode of construction continues.

735. Is that a stone aqueduct or a girder?—In passing round those hill sides the works are proposed to be constructed of the ordinary stone of the country, the excavated trench being made water-tight by a backing of concrete in hydraulic lime. I have here two sections of open aqueduct (*producing several sections*), one with a fall of 4 inches per mile, which

will give a velocity of 109 feet per minute, and a discharge of 28,340 cubic feet—28,000 cubic feet per minute, representing 250,000,000 gallons per day. The next is an open aqueduct, with a fall of 6 inches per mile, which has a velocity of 128 feet per minute, and a discharge of 27,702 cubic feet per minute, being so nearly 28,000 cubic feet that I did not think it worth while altering the design. The third is a section showing a covered aqueduct, with a fall of 4 inches per mile, the velocity of which is 106 feet per minute, and the discharge 28,514 cubic feet per minute. The fourth is a section of covered aqueduct, with a fall of 6 inches per mile, which gives a velocity of 127 feet per minute, and a discharge of 28,575 cubic feet per minute. The fifth section is of a tunnel, which would be 20 feet wide and 15 feet high, with a fall of 6 inches per mile, the velocity of which would be 125 feet per minute, and the discharge 28,240 cubic feet.

736. (*Sir J. Thwaites.*) Can those at any time be under pressure?—Nothing beyond what is due to the depth of the water in the aqueduct.

737. Then they never can be running at the full volume?—They never can. These sections show the covered and open aqueducts near the northern portion of the project, extending as far as Stockport. In some cases you see the word "substructure," which is shown by a green colour; that portion of the aqueduct is proposed to be constructed in this way: it is carried upon arching with a pitched channel backed with concrete, the same in form as the sections which I have just exhibited, and then it is surrounded by an embankment which is made up of the material which has been excavated in the trench on either side of it, and wherever the word "substructure" occurs on that section it refers to this mode of construction; where "arched aqueduct" is given, this is the mode of construction proposed to be adopted—a raised aqueduct carried on arches—in fact it is built and carried upon a viaduct, and the same mode of construction is carried out throughout. Each of those depressions on the section is crossed in the same way by iron pipes.

738. What is the width of the depression which is marked at the 22nd mile on the deposited plan?—About five furlongs.

739. What is the depression?—The depression is something about the same as I gave before—about 140 feet. Between the 26th and 27th mile the section represents an aqueduct carried upon arches, and those are put on merely to show that that mode of construction is contemplated. These would measure about 120 or 130 feet each, whereas they would in reality be only 25 or 30 feet each arch.

740. What will be the length of that aqueduct?—That raised portion on arches would be about 26 chains, or about 572 yards, and the same modes of construction are carried on all through. I see between the 30th and 31st mile that there is another small raised aqueduct. When we come to the 33rd mile, at a place called Lupton Beck, there is an inverted syphon a mile in length.

741. Is the depression about the same?—Probably a little more, about 150 feet I should say at that part. Then the same mode of construction is carried on until we arrive at the river Keer, near Burton-on-Kendal. Between the 37th and the 38th mile there is an inverted syphon of a mile and five furlongs in length.

742. (*Mr. Harrison.*) In passing that spot you do not appear to give more than three feet of fall?—It is calculated for a fall of 1 foot 8 inches per mile. I may mention that there is very great economy in using those large pipes. For instance, three lines of 8-feet pipes, with a fall of 1 foot 8 inches per mile, will discharge as much as ten 4-feet pipes with a fall of 5 feet per mile. The same velocity may be obtained by the water in passing through a large pipe with a small fall as there is in its passing through a small pipe with a large fall.

743. That is one of the reasons why you adopted a wrough-iron pipe with a heavy pressure of 300 feet, in order to get greater strength?—Yes, and also from motives of economy, because we could lay down three lines of 8-feet pipes to convey 250,000,000 gallons of water per day, at a price of nearly 40,000*l.* per mile cheaper than it would take to lay down 10 lines of 4-feet pipes with a fall of 5 feet per mile. In each of those cases I may say that we have assumed the actual discharge of those large pipes at 33 per cent. over the theoretical one, Mr. Bateman having found in the pipes which he laid down at Glasgow, which were 4-feet pipes, that they discharged fully 61 per cent. more than their theoretical quantity. In making that statement I have taken the 4-feet pipes also at 33 per cent. more than the theoretical discharge, and I have added that in each case. That takes us down to 5 miles from Lancaster, and then at a point about 5 miles from Lancaster we can supply that town with water. Onwards from this the work is of a very light nature, with the exception of one or two gorges which are passed by raised aqueducts. Then from the 64th mile onwards there is a great deal more of iron piping.

744. (*Sir J. Thwaites.*) Is the 64 miles measured from the head of Ulleswater?—Yes. The same mode of construction continues, but owing to having to pass a great many depressions a great deal of it is iron pipes. At the 66th mile it is opposite the town of Preston, and from that point at the village of Longridge water might also be supplied. We have about 4½ miles of piping crossing the river Ribble, with an extreme depression of 340 feet. In such portions of the work as tunnels and raised aqueducts, which are the most expensive parts of the project, with the exception of the iron pipes, the fall is kept at six inches, and where it is of comparatively cheap construction, such as may be indicated between the 71st and 72nd mile, the inclination is kept at four inches to a mile. I may mention that the velocities which water would attain in those conduits are something like 20 per cent. greater than the velocity in the aqueduct conveying water from Loch Katrine to Glasgow, and about 20 or 25 per cent. greater than the velocity in the conduit lately constructed for the supply of Aberdeen. It may appear strange that a high velocity can be got by a small fall, but if you will allow me, I will explain that to the Commission in a very few minutes, and I trust that I shall be able to make it very clear. The velocity of water in any aqueduct depends upon two conditions, it depends first of all upon the ratio which the sectional area of the fluid bears to the wetted perimeter or surface with which it is in contact, and secondly upon the fall. The ratio of the section to the wetted perimeter or frictional surface is technically called the hydraulic mean depth, and that is very much greater in large aqueducts than it is in small ones. For instance, here is a rectangular section of a conduit 12 feet deep and 12 feet in width (*producing the same*), and the sectional area of that will be 144 square feet. The wetted perimeter is 36 feet, and 144 divided by 36 will give the quantity of 4, which is the hydraulic mean depth of that conduit. We will now take a small conduit, 3 feet square. The sectional area of that will be 9, and the wetted perimeter of that also is 9, which divided into 9 is equal to 1; therefore in the one case the hydraulic mean depth is represented by 4, and in the other it is represented by 1, and it follows that in the larger conduit, which is 12 feet square, the water would attain the same velocity with a fall of 1 foot per mile, as it would in the smaller one with a fall of 4 feet per mile, or in other words, the velocity which water will attain in a 10-feet culvert with a fall of 2 feet per mile will be precisely the same as the velocity in a culvert of 2 feet diameter with a fall of 10 feet per mile. It is in that way that the velocity is high with a small fall, in fact, the velocities in those conduits are as great as it would be safe to use, and if I had a greater available degree of fall at my disposal I should be afraid to use it excepting for iron pipes. We have just had a very notable instance, in the case of the large aqueduct of the Ganges Canal, 1,200 miles in length; the engineer who planned that designed it and carried

R. Hassard, Esq.

14 Feb. 1867.

it out with a fall of 15 inches per mile, and the result is that the aqueduct has nearly torn itself to pieces. It has produced, instead of an equable stream, a destructive torrent, and they are actually at the present moment obliged to build a number of barriers in the shape of weirs across to stop it and preserve the aqueduct from destruction.

745. (*Col. Harness.*) Is not the part where it is cut through of the worst possible material?—I do not know; I can only speak from what I have heard.

746. (*Chairman.*) Will you proceed with your description of the course of the aqueduct?—At the 85th mile we pass immediately below the Rivington reservoir (which supplies Liverpool), at an altitude of 40 or 45 feet above their pure water basins, so that a supply might be given to Liverpool at that point most advantageously. The same mode of construction is carried on until we get to just immediately south of Bolton, and from that until we get to Stockport, with one or two small intervals in the shape of relief tanks, covered over, the aqueduct would consist of piping, and would be piping till we get to about 5 miles south of Stockport, where the ordinary construction would recommence. I may say that from a point south of Bolton, that is from the 91st to the 96th mile, is the only place in the whole line of aqueduct where any coal workings have occurred.

747. (*Mr. Harrison.*) So far your work has been all laid out from the Ordnance surveys, and not from actual levellings?—Precisely. Out of the first 110 miles there are $16\frac{3}{4}$ miles of tunnel; there are 4 miles of covered aqueduct, $46\frac{1}{2}$ miles of open aqueduct, 10 miles of aqueduct carried on substructure or on arches, as I have explained, and $32\frac{3}{4}$ miles of iron pipe. Those constitute the different parts of the 110 miles. The iron piping is laid out for the supply of the first instalment of 175,000,000 gallons per day, but in the estimate of 13,500,000*l.* for the total scheme we have included the additional pipes to bring in the full supply of 250,000,000 gallons.

748. (*Chairman.*) Have you calculated in the expenses the supply of the pipes to the various towns on the road?—No, because I look on that as a matter which will pay for itself.

749. Do you set off what money you would get for the water against the cost of conveying it?—That is a question which I did not take into consideration, because I looked at it merely in the light that if it was worth while for any town to take water from us it would be worth our while to construct works to supply them, for we pass in every case almost close to the towns, or at least within easy distance.

750. You are 25 miles from Liverpool, are you not?—Yes, but we are only a quarter of a mile from their pure water basins, into which we should deliver the water. Here is a drawing (*producing the same*) showing a tank at the end of each of the three lines of pipe, and those pipes are furnished with sluices by which the water can be shut off from any one of them at any time, and they can be emptied at the lowest point and examined internally, and can be traversed from end to end. In addition to the ordinary valves they are proposed to be furnished with what we term momentum gates, and in the event of a fracture or accident happening to any of those pipes those gates would close themselves, so that the only damage which could ensue would be by the water which is already in the pipe escaping, and the supply would be shut off. There is a pendulum hung near the mouth of the pipe, and it is so adjusted that it is not moved by an ordinary current of water passing through, but in the event of a fracture, which would bring a rush of water into it, the valve would assume the position shown by the red line, the gates would then close, and the supply to the pipe would be then shut off.

751. (*Mr. Harrison.*) Is the 110th mile the point to which the contour lines enable you to carry your sections?—Yes, we have only, of course, the one-inch survey beyond that point, but I have brought with me maps which show the levels which we have got from canals and from railways, and from different other sources, which enable us to fix with great accuracy the line of the aqueduct, so that the deviation from that line would be comparatively of a very trifling nature. This small Bradshaw's map which I produce will show the assistance which we have derived from the Ordnance lines of levelling, the blue lines indicating the main Ordnance lines of levelling, which for a considerable distance pass almost along the line of the aqueduct, and cross it at two other points. Stockport is the point where I described that the contour Ordnance maps end, and from thence the line takes a route passing outside the Staffordshire coal field. Those heights which are indicated in red are all heights along the line of aqueduct, which have been ascertained from the Ordnance or from other lines of levelling.

752. How far are you at the nearest point from the Staffordshire coal field?—About half a mile, and it can be kept further if it is necessary.

753. Do you consider that half a mile is a sufficient distance to prevent the water from being impregnated?—Yes, it is on a different geological formation.

754. Will you tell us what the geological formation is at the nearest point to the Staffordshire coal field through which the aqueduct will be carried, within half a mile?—The geological formation at that point is the new red sandstone. I may point out that immediately after, about four miles to the east of Bolton, where I described that there have been some coals found, there is a line of permian marls and new red sandstone lying to the east of Manchester, along which the line of aqueduct is carried. There is a band of permian marl intervening between the red sandstone and the coal measures. From Macclesfield onwards the line passes to the west of the Potteries, passing round the south-western portion of the Staffordshire coal field. There the formation is permian marls and new red marls, lias shales, limestone, oolites, shale, chalk, the Wealden clay, the Oxford clay, and so on (*describing the same on the map*). From the Potteries we proceed onwards, in a south-easterly direction, along the table-land known as Needwood Forest, and and we cross the river Trent about four miles to the south-west of Burton-on-Trent, the elevation of the aqueduct itself there being between 340 and 350 feet. The river itself is 160 feet, and there would be a depression consequently there of about 200 feet. Having crossed the river Trent we get upon the table-land of Charnwood Forest, and pass onwards to the district traversed by the Ashby-de-la-Zouch canal, and to give the Commission a notion of the nature of that part of the country, I may say that from Ashby-de-la-Zouch to Rugby, a distance of about 55 miles, measured along the canal, it is in one level reach. From Rugby onward towards London the line of aqueduct follows in a great measure the route of the Grand Junction Canal and the London and North-western Railway, and it terminates in regulating reservoirs to be constructed north of Edgeware, at an elevation of 220 feet above high water, which is considered ample for London; and from that point we propose to distribute to the existing reservoirs of the existing waterworks, and utilize as far as possible the present means of distribution. The districts supplied by the works of the various water companies in London may be looked upon as contiguous cities, and any attempt to introduce a new system altogether would be attended with great unnecessary expense, and lead to the uncalled for abandonment of a great portion of the present works. From those regulating reservoirs the service reservoirs of the existing companies will be supplied, so as to avoid as far as possible the abandoning or not making use of the present means of distribution.

755. Now will you describe the geological formation of the gathering ground, beginning at Ulleswater?—The gathering ground of Ulleswater is the Silurian slate, except one small portion of old red sandstone which appears at the north end of Ulleswater. There is a very

small portion, about six miles long by two miles broad, that is about 12 miles out of 180, which is old red sandstone, the rest being Silurian slate.

756. (*Mr. Prestwich.*) Do you suppose that you can convey the water without lining the aqueduct?—It is probable that in the construction of a great portion of the open aqueduct it may be constructed without a lining, but we include the cost of lining it all. The aqueduct then traverses the Silurian shales and sandstone. For a short distance of about two miles near Kirkby Lonsdale it passes through the lower limestone shales, it then enters the millstone grit, and continues in the millstone grit, with one or two exceptions, where crossing the valleys of rivers we meet with the upper limestone, but as the depressions would be crossed by iron pipes, the geological formation is not a matter of much importance.

R. Hassard, Esq.
14 Feb. 1867.

757. There are no parts of the geological formation of a nature to present any engineering difficulty?—No.

The witness withdrew.

Adjourned to Wednesday next, at half past 11 o'clock.

Wednesday, 20th February 1867.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND IN THE CHAIR.

Sir JOHN THWAITES.
Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

RICHARD HASSARD, Esq., further examined.

R. Hassard, Esq.
20 Feb. 1867.

The witness delivered in the following statement:

DATA on which the WORKS for supplying DUBLIN and SUBURBS with water from the river VARTRY were projected by RICHARD HASSARD, C.E., in the year 1858.

The population of Dublin with its maritime suburbs was then about 300,000, and the least quantity of water it was deemed desirable to secure the control of, in the first instance, was 12,000,000 gallons daily; it was, however, held to be indispensable that this supply might be augmented at trifling cost, as the demand for water increased in the future.

Almost all the mountain ranges near Dublin being covered with vast beds of peat, and the streams flowing from them consequently tainted, and being also used largely for mills and manufacturing purposes, it became necessary to seek the supply from some elevated district, free from these objections.

A district in every way eligible was found in the county of Wicklow, although at a considerable distance. The drainage area extended over about 16,640 acres, and was partly of granitic and partly of silurian formation; it contained but little peat and there were excellent sites for the necessary reservoirs.

The water from the district, however, flowing in a southerly direction, it became necessary to reverse it, and carry it northwards to Dublin by tunnelling through an intervening mountain range.

This project possessed the advantage of being able to supply from the main aqueduct, *in transitu* to Dublin, the several fashionable watering-places and suburbs of Bray, Killiney, Dalkey, Kingstown, Monkstown, Black Rock, Booterstown, and Sandymount, situated on the south side of Dublin Bay, and dependent for water on wells and the rain collected from the roofs of the houses.

The only question in doubt was the rainfall, and on this much discrepancy of opinion existed. The rainfall in Dublin, at an elevation of about 100 feet above the sea, for the 16 years from 1837 to 1852 inclusive, not averaging more than 29 inches, whilst for the year 1847 it was only 24 inches; it was obviously therefore unsafe to take the mean of three consecutive dry years at more than 27 inches.

No gauges having been kept in the Vartry drainage area, the only mode of determining the additional amount of rain due to the greater mean elevation of the Vartry district (960 feet) was by investigating the results ascertained in other places to be due to this cause.

These left no doubt that an additional quantity of about 30 per cent. might fairly be relied on, thus bringing the mean rainfall of the Vartry district, in three consecutive dry years, up to 35 inches. (This was borne out by the returns of a gauge kept in the vicinity, but the existence of which was not known at the time.)

Deducting 14 inches for loss from evaporation and absorption there remained 21 inches as applicable for town supply and compensation, and deducting one third for compensation, this left, for town supply, 14,480,218 gallons daily.

The supply can at any time be largely increased by extending the works in the direction of Lough Dan and Lough Tay.

758. (*Chairman.*) Is there any explanation which you wish to give with regard to any part of your former evidence?—Yes; some matters escaped me at the time, which I should like to refer to to-day. With regard to question No. 684, the purport of the question was whether the parties living on the river Eamont would not get the drainage from the lead mines in a more concentrated form than at present, by the means which are by our plan proposed to be adopted, and I answered that they would. But I should wish to extend that answer, and say that by constructing settling tanks at the north end of Ullswater, the drainage from the lead mines might there undergo precipitation and be delivered into the river Eamont in a state not more objectionable than at present. In fact, it would be so largely diluted with water and so comparatively pure by the process of precipitation that no ill effects would arise.

759. (*Sir J. Thwaites.*) I understood that your first object was to intercept that water from flowing into Ullswater so as not to contaminate the source of your supply?—Yes.

760. You propose to bring it by means of pipes down to Pooley bridge and then to discharge it into the river Eamont?—Yes.

761. His Grace's question was, whether if you were to discharge it into a smaller volume of water than into the lake itself it would not injure that river. I understand your amended answer to be that you propose to construct settling tanks at the north end of the lake and then after precipitating the colouring matter, whatever it may be, to allow the clear water to flow off into the river Eamont?—Yes, although I believe that the injury which would be done to the water in the lake if it was discharged into it towards its northern end at a considerable distance, say three or four miles, from the point where the water would be drawn off for London would be so little that the water would be innocuous, yet at the same time I should prefer passing it into the river Eamont at Pooley bridge. The town of Penrith which is now supplied by pumping water from the river Eamont immediately adjoining could then be supplied with purer water than it gets at present by piping water from Ullswater.

762. It is a considerable distance, is it not, from

R. Hassard, Esq.

20 Feb. 1867.

Ullswater to Penrith?—It is about 4½ miles to the point where they pump, it would not be a serious expense; they take the water from below the bridge.

763. And before it joins the Lowther?—Yes, before its confluence with the Lowther.

764. (*Chairman.*) That would be an addition to your present scheme?—It would be a small additional expense, but it is fully provided for in the contingencies that we have estimated for.

765. Was there any other point which you wished to clear up?—Yes; relative to the construction of the open conduit, I omitted to mention that wherever a public road crosses the conduit we have allowed in our estimate for covering it 50 yards on either side of the centre of the public road, so that wherever it would be crossed by public traffic it would be to all intents and purposes a covered aqueduct.

766. (*Sir J. Thwaites.*) You mean 50 yards in addition to the bridge?—The bridge or covered part of the conduit would be 100 yards in length.

767. You would fence the bridge off a reasonable width, would you not?—Yes, we should fence the bridge off for the width of the present road, and cover the culvert 50 yards on either side of the centre of that road up and down the stream.

768. (*Chairman.*) Is there any other point which you wish to explain?—Yes; relative to the mode of drawing off water from Haweswater and from Thirlmere, I mentioned that we intend raising those lakes, I think, 42 feet in the one case and 64 feet in the other, but we intend to draw off the water 15 feet below the present surface of those lakes, and to draw off in both cases by tunnels, so as to avoid the danger of constructing culverts through embankments; there will be tunnels through the rock.

769. (*Sir J. Thwaites.*) And that gives you the holding capacity so far as you are concerned?—Yes, it increases our capacity of storage, and the water would be drawn off through iron pipes laid in tunnels driven through solid rock.

770. Your calculation is based upon the invert of your pipe 15 feet below the present level of the lakes?—Yes.

771. That is not the storage of the lake itself?—No, the lakes are deeper than that.

772. Haweswater is nearly 300 feet deep, is it not?—It is an immense depth, I do not know the precise depth. The quantities of all those reservoirs have all been taken out by cross sections, so there is no question as to their capacity. There is one other matter with regard to which I should like to give an extended answer. His Grace asked me whether I had made provision in the estimate for works for supplying other towns with water, and my answer was that I had not, that the sale of water would pay for itself or something of that kind, but what we should do is this—we should supply water in bulk, we should supply towns adjoining our works with water, and sell it to them all at the same rate at which we should be able to deliver water in London, that is to say, at about 10*l.* per 1,000,000 gallons, or 2·4*d.* per 1,000 gallons, and we should let the towns do everything else after that. We should supply the water in bulk leaving them to do the rest, and to charge any price they liked to their customers or to the inhabitants respectively. It is a very usual way of managing the matter, it is intended to be so done in Dublin at all those places which you see coloured on the map green, as the towns are to be supplied in bulk and the corporations or authorities of the towns then take charge of the distribution.

773. They would, in point of fact, construct their own works?—Yes, such additional works as might be necessary.

774. They would construct them up to your tunnel?—Yes, up to our aqueduct.

775. (*Chairman.*) Would not that be constructing the whole of the works?—Yes, such additional works as were necessary for an extended supply; if they wished to extend their supply in any direction they would have to construct the additional requisite works, as a matter of course.

776. (*Sir J. Thwaites.*) You would merely supply the raw material?—Yes; we should supply it in bulk and let them retail it or distribute it as they pleased.

777. (*Chairman.*) But they would have to store it at those places, would they not?—No; there would be no storage necessary, or a very limited storage, perhaps 3 or 4 days supply to guard against any accident to the works; but the body of water in the aqueduct would be constant, and we could supply day by day the quantity which would be required. The storage would be in the lakes, and the quantity that we should draw off daily would be constant.

778. (*Mr. Harrison.*) If you will be so good as to refer to your answer to question No. 743 in your former evidence, you will see that you say there, "In each of those cases I may say that I have "assumed the actual discharge of those large pipes "at 33 per cent. over the theoretical one, Mr. "Bateman having found in the pipes which he laid "down at Glasgow, which were 4 feet pipes, that "they discharged fully 61 per cent. more than their "theoretical quantity." Is that correct?—It is correct so far as this, that Mr. Bateman stated that there could be no doubt that the pipes discharged a quantity at least equal to 40 to 50 per cent. above their theoretical quantity; but I calculated carefully what they actually did discharge and I fond it to be 61 per cent.

779. You say Mr. Bateman having found that they did so?—So far as that expression goes that is not quite correct. From 40 to 50 per cent. was Mr. Bateman's actual expression, and my calculation gave 61 per cent.

780. Then this statement of yours requires correction?—Yes, certainly.

781. Where do you find that statement of Mr. Bateman's?—It is in the evidence before the Metropolitan Sewage Commission. In his evidence before that Commission Mr. Bateman stated that in the Glasgow waterworks 4 feet cast-iron pipes, with a fall of 5 feet per mile, were calculated to deliver 20,000,000 gallons daily, and that with a fall of 3 feet 6 inches per mile is 61 per cent. more than 16,300,000 gallons which is the theoretical quantity a 4 feet pipe would deliver with that fall. Further on in his evidence Mr. Bateman stated this. He was asked to what cause he could attribute that, and he said that it was owing either to the coating of the inside of the pipes with Dr. Angus Smith's preparation of coal-tar, which rendered them very smooth, or it was because the formula which we have hitherto used for those calculations was made upon a much smaller class of pipe than has been lately introduced; but from whatever circumstance, he said, there is no doubt that those pipes discharged from 40 to 50 per cent. more than their theoretical quantity.

782. Perhaps you are not aware whether that large increase of discharge has continued, or whether, as I believe is the fact, it has been gradually diminishing?—That I am not aware of.

783. I understood from Mr. Bateman that owing to the different state of the pipes, they being in the first place almost like glass from the application of this mixture, from that mixture either decaying or otherwise since the period at which he made that statement, the discharge has gradually been diminishing?—I think it is probable, although I am not aware of the fact. I may observe that the coating of Portland cement, which we propose using inside our pipes, is imperishable, and we believe that it will have precisely the same effect of giving a smooth surface which Dr. Augus Smith's preparation gave in the Glasgow case, and we do not anticipate any diminution of the discharge in consequence of the state of the lining.

784. Will you just refer to the next question, No. 744, in answer to which you say, "I may mention that "the velocities which would be attained in those con-"duits are something like 20 per cent. greater than the

"velocities in the aqueduct conveying water from "Loch Katrine to Glasgow, and about 20 or 25 per "cent. greater than the velocity in the conduit lately "constructed for the supply of Aberdeen." On what basis do you assume that your conduit will discharge at a velocity from 20 to 25 per cent. greater than is obtained in the cases of Glasgow and Aberbeen?—I know that the velocity in the Glasgow aqueduct is from 100 to 105 feet per minute, and I have calculated the velocity in our aqueduct, and it is something like 120 feet per minute.

785. Does not what you are now assuming rather go to disprove the accuracy of the formulæ, which are in constant use, with regard to discharge of water by rivers?—No, there has been no variation found out as regards the discharge of conduits.

786. In that answer you refer, do you not, to conduits?—But that increased discharge in the Glasgow case applied only to pipes under pressure used as conduits; we have assumed no variation from the ordinary formula for conduits lined with masonry.

787. You say, "I may mention that the velocities which are attained in those conduits;" does that mean your pipes?—No, the expression conduits is certainly applicable to both pipes and open and covered aqueducts, but there is no per centage of increase assumed for the aqueducts of masonry; the actual discharge has been calculated and the actual velocity.

788. Does not this rather lead to the assumption that you do calculate 20 per cent.?—No, certainly not; I did not intend to convey that.

789. Will you have the goodness to put that matter quite right?—I say "I may mention that the velocities "which would be attained by water in those conduits "are something like 20 per cent. greater than the "velocity in the aqueduct conveying water from "Loch Katrine to Glasgow." There is only a small portion of the aqueduct from Loch Katrine to Glasgow, which is composed of iron pipes. It is an ordinary covered conduit and tunnel.

790. (*Sir J. Thwaites.*) How do you get that 20 per cent. increase?—It is owing to two causes, as I mentioned the other day. The velocity of the water in a conduit is dependent on two things: it is dependent on the body of water in the conduit and upon the fall, and an aqueduct with a large sectional area conveying a large body of water will convey it at a velocity the same as will be attained by a much smaller culvert with a greater fall. It will be remembered that I said that water flowing through a 10 feet culvert with a fall of 2 feet per mile will have precisely the same velocity as water flowing through a 2 feet culvert with a fall of 10 feet per mile.

791. (*Mr. Harrison.*) You say I "may mention that the velocities which are attained in those conduits," what does "in those conduits" refer to?—By those conduits, I allude to open and covered aqueducts and tunnels, not to pipes; I allude to the whole of the aqueducts excepting the pipes.

792. Then in fact you calculate upon a velocity of something like 20 per cent. greater than the velocities in the aqueduct conveying water from Loch Katrine to Glasgow?—I say that our aqueduct will convey water with a velocity 20 per cent. greater than the Loch Katrine aqueduct does, both being calculated from the same formula. Not the pipes, but the open and covered aqueduct, owing to its large size, will convey the water with a velocity 20 per cent. greater than that which the water attains in the Loch Katrine aqueduct, though the latter has a much greater fall.

793. Your answer hardly conveys the impression that it is 20 per cent. greater than the velocity in the aqueduct, because there is nothing to compare it with; we have not here sections of the Loch Katrine aqueduct, and your answer conveys a wrong impression?—Not so. There are the sections (*producing the same*). The Loch Katrine aqueduct is 8 feet wide and 4 feet deep at the springing of the arch in its ordinary construction, and, therefore, there is a very large amount of frictional surface in contact with the water compared with what there is in our aqueduct, owing to its greater sectional area.

794. You do not mean to dispute the ordinary formula upon which all those calculations are made?—Certainly not.

795. Not in the case of the conduit?—Certainly not. Our calculations, for the open and covered conduits, are based on it. There was one point relative to the construction of the tunnel by which we propose to draw the water off from Ullswater, on which I should wish to make a remark. It was stated, that from the rate of progress which was made at Loch Katrine, it would very likely be a work of a great period of time. I beg to hand in a statement of the progress which has been effected in the Mont Cenis tunnel during the years 1863, 1864, and 1865. In the year 1863 at the Bardonnéche end, that is the Italian end, the rate of progress averaged 3·84 feet per day. At the Modane end, that is the French one, it averaged 3·80 feet per day. In 1864 at the Italian end, it averaged 5·58 feet per day, and in the same year 1864 at the French end, it averaged 4·19 feet per day. In the year 1865 it averaged 6·88 feet per day at the Italian end, and 4·11 feet at the French end.

796. (*Col. Harness.*) Are those days 24 hours?—Yes; they work night and day.

797. (*Chairman.*) Then what you call a day in that table means 24 hours?—Yes; they never stop in the tunnel; they work night and day. I shall also read an extract from a report of Captain Tyler to the Board of Trade on the subject of the proposed railway over Mont Cenis, in which he treats of the rate of progress which has been maintained in the construction of this tunnel. This report is dated the 12th of June 1865, and in page No. 1, he states, "I took the "opportunity of visiting this tunnel. I found that "headings had been driven for 2,011 metres from "Modane, and 2,700 metres from Bardonnéche, "leaving 7,509 metres (about 4⅔ English miles) to be "yet pierced." In page No. 2, he states, "Looking to "the state of progress which has hitherto been effected, "and the probable nature of the rocks, it cannot be "expected, without taking into account any extra "difficulties of ventilation, or from water which may "be encountered, that this tunnel can be completed "in less than from seven to eight years." Upon that I may make this note, that taking the time as eight years, this would give a daily average of about 4 feet 3 inches at each end or working face, and that was for the central or the most difficult part of the tunnel where they were two miles from either end. In the construction of the Kirkstone Pass tunnel, we have estimated the rate of progress at 4 feet per day at each face.

The witness delivered in the following statement:

TABLE showing the Progress of MONT CENIS Tunnel effected by the boring machinery there, during the years 1863, 1864, and 1865.

At the Bardonnéche end (Italy).	Metres.	Feet.	Feet per day.
1863	426	1,398	3·84
1864	621	2,037	5·58
1865	765	2,510	6·88

At the Modane end (France).	Metres.	Feet.	Feet per day.
1863	367	1,204	3·80
1864	467	1,532	4·19
1865	458	1,508	4·11

R. Hassard, Esq.

20 Feb. 1867.

798. Are you aware whether the works on Mont Cenis tunnel have gone on with the same degree of speed at both ends?—At the Bardonnéche end the works have gone on with a greater degree of speed; at the Modane end they have been working for nine months through some hard quartz, and in that case they have averaged, I think, 2·80 feet per day, but that quartz they anticipate that they are nearly through now. But a great increase has taken place at the Bardonnéche end, greater than I have put in that table.

799. Since that report of Captain Tyler's, the rate per day having been exceeded at one end and having diminished at the other end, what would that bring the average down to?—It still leaves a greater average than 4 feet.

800. You have described the mode of construction of your aqueduct up to Stockport; will you proceed now to describe the construction for the remainder of the way?—Through the midland counties where we get to a great extent out of the rock formation that we pass through the whole distance from Ullswater to near Manchester, at all events when we get beyond the Potteries, we should get into the clay districts of Leicestershire and Northamptonshire, and for that portion of the work where it is much lighter, a rather different mode of construction would be adopted, something in the manner shown in this section (*producing the same*). We should use Portland cement concrete to a great extent, which forms an imperishable material, and line the aqueduct with bricks, putting the upper portion, where it might be exposed by the variation of the level of the water, of Staffordshire bricks. That section shows one mode of construction and the other side shows the conduit with a rendering or a coating of Portland cement, which is found to be a most durable material. They are constructing now a sewer in London wholly of Portland cement concrete, and using no brick at all; I refer to the sewer at Bridge road, Battersea. This section shows a piece of covered way constructed of Portland cement concrete protected with brick; the bottom is covered with a Portland cement rendering, and the arching is of brick in the ordinary way. If we met with rubble we should use it, backed with concrete, for the sides and bottom, something in the same way as rubble is proposed to be used in the northern portion. The one section shows a fall of not quite 5 inches per mile, it being 28 feet in width at the water line. The other section is for a fall of 6 inches per mile and 26 feet in width at the water line. Some fear was expressed as to the raised aqueduct. I have drawn an alternative one which can be made at the same expense. It is proposed to be made on iron ribs with cast-iron plates between, such as Mr. Harrison is aware are used for tanks at railway stations. Those ribs are 4 feet apart and they are tied across at the top with a piece of rolled girder, which effectually supports the structure and affords the means of carrying a foot-path along it.

801. (*Mr. Harrison.*) It is merely a question of price I presume?—This plan is just about the same rate of price as the one I showed you before.

802. (*Chairman.*) Is what you have just described the mode in which you propose to carry the water through the midland districts?—Yes.

803. That is the method you adopt from Stockport till you get to where?—To the reservoirs near London. There might be some short bits of tunnelling on the route and they would be constructed with brick in the ordinary method.

804. (*Sir B. Phillips.*) You spoke, did you not, of coating this aqueduct with cement?—We should either face the concrete with brick or render it with cement.

805. Would there be no fear of corrosion eventually to the lining of the aqueduct from the action of the water?—Not the slightest. Portland cement is perfectly imperishable when it is of good quality.

806. (*Mr. Harrison.*) Of course, that is the important question, that is the great difficulty which all those who have to use it, I think, must admit?—The weight and the colour are sure tests. We find no difficulty at Barking in the construction of the metropolitan sewage works, inasmuch as from the weight and the colour we have the means of detecting at once any inferior quality.

807. (*Chairman.*) You consider, do you not, this part of the country which your aqueduct will traverse to London comparatively easy?—Compared with the other part, very easy indeed.

808. (*Mr. Harrison.*) Have you prepared any approximate section of it?—Not of that portion, but I have the Ordnance maps here with such an immense number of levels upon them that as to leave the selection of the route a matter of no difficulty, and they also enable us to make a very fair estimate of the probable amount of the work. The whole aqueduct from Ullswater to London averages 37,000*l.* per mile as against 38,000*l.* at which Mr. Bateman estimated his aqueduct. There is no very great difference between the two as to cost, Mr. Bateman's is a little more expensive in construction, he has contemplated using a much larger amount of brick, judging from the drawings which he exhibited here, whereas where we pass through a rocky country we use the rubble of the country.

809. But taking the simple assumption that in both cases you adopt the same form of conduit or the same form of aqueduct, he having at his power a larger fall per mile than you have, his works would be less than yours throughout, would they not; not in the direct ratio of the fall, but in something, perhaps, approximating to the square root of the fall?—Possibly that may be so, but I should be afraid to work with a greater velocity.

810. You mean in a lined conduit all through?—Yes; the aqueduct for either of these projects should be a work for all time, and any stoppage for repairs or anything of that kind would be a very serious matter. If I had a greater fall I should use it in the syphons, and I should put a smaller capacity of pipe with a greater fall; but I should be afraid to work with a greater fall in the conduits and tunnels in the ordinary portions of covered and uncovered aqueduct.

811. I should differ from you; but taking it irrespective of that question, there can be no doubt that the position which I put to you is perfectly correct?—Quite so.

812. Do you think that in a matter of such vast importance as a work embracing 12,000,000*l.* of capital you, as an engineer, would be prepared to advise any parties to undertake such a work upon an approximate estimate, without actual sections of the country being taken?—Yes; I think that I have quite sufficient information to warrant me in making the assumption that the estimate is sufficient.

813. Within what per centage of the probable cost do you think you could fairly assume that you could arrive?—I believe that it could be done, and I believe that the estimate which I have given would not be exceeded. I know that it would not for the most northerly and most difficult portion of the work, because there we had the advantage of sections, and the thing has been gone into very carefully. I believe that the price which we have allowed for the remainder of the work would be ample to cover it, and would not be exceeded.

814. Without knowing how many miles of that work would be by piping, or how many miles would be by aqueduct, or what the extent of those aqueducts would be, you think that you could still arrive at a justifiable calculation?—I think so. Both projects are open to the same objection, but there would not be more than 10 miles of iron pipes, and that would be at the crossing of the Trent, and of that I have satisfied myself.

815. Approximately you could have prepared, could you not, a section so as to have sufficient heights throughout the whole of that distance, or you could have prepared a section in continuation of your

existing one ?—I will show you the information which I have got, and you shall judge for yourself.

816. Have you put that information in the form of sections ?—No, I have not.

817. What would be the probable cost of taking such sections as would enable you to complete your sections from end to end ?—That, of course, would be a matter of considerable cost for any private individual to incur, because if that were to be done, I think that it ought to be done well, and it would require a great deal of contouring and close examination of the country, but if such a scheme as this were determined to be carried out it might be done without any additional expense by the Ordnance authorities doing it ; they have levels all through the district, and it could be done by them as part of the national survey at a comparatively very small cost, but it would be a very heavy undertaking for any private individual to incur.

818 (*Chairman.*) How do you propose to construct the reservoir near London, and at what place do you propose to put it ?—About a mile north of Edgware is the place where we propose to construct the service reservoirs ; we should have them in duplicate, so that one might be cleansed while the other was in use.

819. What would be the size of each part of the reservoir ?—We have estimated them to contain 15 days supply at 250,000,000 gallons per day.

820. Do you intend that the 250,000,000 gallons should be contained in the whole reservoir or in each part ?—The 12 days supply at 250,000,000 gallons per day would be contained jointly in the two compartments of the regulating reservoir, and that would at an altitude of 220 feet above high-water, and 232 feet 6 inches above the Ordnance datum.

821. (*Sir B. Phillips.*) Do you think that a reservoir containing a supply for 15 days only would be sufficient ?—I think that it might be enlarged afterwards, at any future time additional reservoirs might be constructed if it was found not to be sufficient, but I apprehend that it would be sufficient.

822. Would it be safe with a population of 3,000,000 people to leave a supply of only 15 days, subject to any casualty that might happen ?—The reservoir might be made to any extent that was thought necessary.

823. What is the length, from point to point, of the line of aqueduct that you propose from Ullswater to London ?—From Ullswater to the reservoir is 270 miles.

824. (*Chairman.*) Will you describe the mode of construction of this reservoir at Edgware ?—It is intended to be constructed in the ordinary way, with sloped sides faced with stone or concrete.

825. (*Mr. Prestwich.*) Will you proceed with your description of the geological formation of the district through which the aqueduct is to pass, and first of all in the district through which you pass from the lakes to Manchester, do you pass through any coal formations ?—We pass for some distance over the coal measures, but for a very short distance over a locality where there have been any coal works. For four miles we pass over a locality where there have been a few coal workings, I believe that they are now abandoned, but I do not attach the slightest importance to the subject of coal measures. On those coal measures are situated all the reservoirs and waterworks, of those towns for the supply of which Mr. Bateman stated to the Commissioners the other day that no additional water is needed. On those coal measures are situated the great reservoirs supplying Liverpool, the great reservoirs of Rivington and Anglezark. The line of pipes conveying water to Liverpool is laid for a distance of probably 20 miles over those measures. The towns on those coal measures that have their own waterworks, as Mr. Bateman stated, are Blackburn, Over Darwen, Haslingden, Accrington, Heywood, Bury, Burnley, Middleton, Bolton, Oldham, and Rochdale ; they are all situated on the coal measures, and have their works of water supply existing on them, and in addition the whole country is studded over with reservoirs for canals and for mill purposes ; it is covered with towns, with manufactories, with dye works, chemical works, and with cotton mills, and it is intersected by canals, rivers, and railways, and no inconvenience is found to exist ; but over that four miles where there have been some coal workings we propose to lay four pipes, we will say, instead of three, laying them between the tanks at each end of those four miles, and some considerable distance apart, in fact, having a spare pipe, so that if accident happened to any one of the pipes the valves upon it would close, and the supply would be carried on through the remaining three. This map which I produce shows the line of aqueduct passing over a portion of that district on which, as I have mentioned, are situated the great reservoirs supplying Liverpool. You will also observe the Belmont reservoir, the works supplying Bolton, and other reservoirs and millponds all over it, and on the next sheet also you will find that there are a great number. On those four miles we propose to lay the pipes at some distance apart and, in fact, to lay an additional pipe. You may see how this country is covered with reservoirs. The portion near Bolton is covered with reservoirs, with mills, and with millponds, intersected with canals, with rivers, and with railways ; and the waterworks of all those towns are situated on those coal measures, and, as I have said, no difficulty is found to exist. But we propose to guard against accident, by having, in point of fact, for that four miles works as it were in duplicate, about a couple of hundred yards probably between each line of pipe.

826. If any slight subsidence occurs in a canal, it is easy to raise the level, but with pipes it is very different ?—In the case of an open canal, if fracture takes place in the bed owing to any subterranean working or anything of that kind it might drown the mine or working, because there could be no means of shutting off the water in the aqueduct ; but in the case of pipes, we should place what are called momentum gates or valves at each end, and if any fracture took place, the valves at each end of the fractured pipe would close, and the escape of water would be limited to whatever was in that section of the pipe.

827. You are probably aware that although you may only pass over four miles of actual coal workings, still, as it has been proposed to carry your aqueduct over the permean and the new red sandstone, it is possible that coal may exist under those formations which may be worked ?—No doubt it is so ; and in the portion of the aqueduct just north of Rivington, where there has been no coal working, and where, I believe, it was attempted once or twice and abandoned from being found not worth working, it would be very easy to buy a stripe of land on either side of the aqueduct so as to prevent its being underminded underneath, and that land could be let for agricultural purposes and so pay the interest upon its purchase.

828. The district to which the last question which I put to you had reference was the permean and the new red sandstone district of Cheshire ; is it not possible that coal may exist under those formations ?—I can only say that there are no coal workings there now ; of course, it is not easy to say where coal may or may not be found.

829. And if it were, you would anticipate no difficulty on that score ?—No difficulty whatever, and the remainder of the aqueduct avoids all the known coal fields.

830. You pass close by the Staffordshire coalfield, do you not ?—Our aqueduct passes round the south-western portion of the Staffordshire coalfield, from that it passes on along the table land of Needwood forest, crosses the river Trent about five miles south-west of Burton ; that is where the 10 miles of pipes probably would be. It then passes along the table land of Charnwood forest till it gets into the country traversed by the Ashby-de-la-Zouch canal, which is 53 miles in one level reach, and will give some idea of the easy nature of the country there.

R. Hassard, Esq.

20 Feb. 1867.

831. (*Mr. Harrison.*) What is the level above the Ordnance datum of the canal there?—315 feet; we should be something greater than that, about 330 feet; but the ground is all gently sloping and we can get any elevation we please.

832. (*Mr. Prestwich.*) For what distance do you pass over the permean and new red sandstone?—About 30 miles in the Cheshire district, and there are about 65 miles of the new red marls in addition,

833. Then you pass, do you not, over the oolites?—Then we get into the lias shales and limestone; then we get into the oolites and shales: then into the Oxford clay; then into the galt clay; then into the chalk, and lastly into the London clay.

834. Do you pass over the chalk area without tunnels?—No; there would be a tunnel common to both projects passing through the chalk, north of Watford.

835. Could not that tunnel be avoided by following the line of the canal; you are aware probably, of the great difficulty that was experienced in making that Watford tunnel, from the occurrence of sand pipes?—I know the engineer of that tunnel, and we had some discussion the other day on that subject, and from what he said I did not gather that that was his experience.

836. I visited that tunnel whilst it was in course of construction, and I remember that a very serious accident happened and a great deal of difficulty was experienced from the surface of the chalk being deeply indented with pipes of sand and gravel which they came upon unexpectedly and which gave way, in fact, there were pot-holes of gravel?—We should be deeper in the chalk than that, and the probability is that we should not meet with those.

837. (*Mr. Harrison.*) Is Shiffnal near Mr. Bateman's aqueduct?—Mr. Bateman's aqueduct passes some distance south of it.

838. Do you go close to Stoke?—We pass just outside the Staffordshire coalfield.

839. (*Chairman.*) At what do you estimate the cost of making the reservoir in London?—500,000*l.*

840. (*Sir J. Thwaites.*) That you can calculate, I presume, with something like certainty?—I did not take it out in very great detail; I calculated it according to the cubical contents.

841. How do you line it?—With concrete, and face the upper portion of it probably with brick, the lower portion we should line with Portland cement.

842. What depth of concrete would you use?—That would depend upon the material behind. Where it is London clay, an average of 18 inches would be sufficient; it might be a little less at the top and a little more at the bottom.

843. (*Mr. Prestwich.*) Does not Mr. Bateman provide for a three weeks supply?—No, I think not. I think it is only 15 days.

844. Are you not mistaken in that, he mentioned 21 days, did he not?—I do not recollect, but we have the same amount allowed for that reservoir, so that if Mr. Bateman could make it to contain 21 days supply for that money, we could do it. I have estimated it at a higher cost than Mr. Bateman.

845. (*Sir J. Thwaites.*) Then the cost of your scheme terminates at that reservoir?—The project may be said to terminate there, but we estimate for an aqueduct into London; the connections with the present works of the companies we have not included, and I think that Mr. Bateman has not done so either.

846. (*Chairman.*) Can you state to the Commissioners the total cost of your scheme from the lakes until you bring the water to the reservoir at Edgware?—Until we bring it into London, it is 13,500,000*l.* for a daily supply of 250,000,000 gallons.

847. Does that include everything?—Yes, everything.

848. That being the cost of bringing that quantity of water 270 miles?—280 miles altogether to London. The total cost of works, including contingencies, is 11,679,260*l.*, and to that we have added 1,820,740*l.* for interest on borrowed money during the construction of the works, being an average of something about two and a half years, and for other expenses which, of course, are contingent upon carrying out great works of this nature; we calculate an average of two and a half years, that is, supposing that the works take five years in construction.

849. (*Sir B. Phillips.*) During the progress of the works you charge 1,820,740*l.* for interest upon the principal?—Yes, to cover the interest upon borrowed money and professional and other expenses.

850. (*Chairman.*) With your experience of other works do you think that these works could be completed within five years from the scheme being sanctioned?—I have no doubt in the world that they could. The tunnel at Kirkstone Pass is the key of the whole, and with the same means and appliances that have been used at Mont Cenis, the tunnel, including the shafts and everything of that kind, could be carried through or completed in four years, or in four years and three months at the outside.

851. Would the 13,500,000*l.* include the purchase of land and compensation?—Yes, everything, land, compensation, easement, severance, and every other expense.

852. You object, do you not, to the scheme which has been propounded by Mr. Bateman?—I have some objections to offer to the Commissioners, but before I do so, I may probably as well hand in a list of the towns with their populations to which supplies could be given from our proposed aqueduct *in transitu*, either in aid of their existing supplies or wholly, if they choose to take it.

The witness delivered in the following table:

LAKE PROJECT.

Towns.	Population in 1861.	Towns.	Population in 1861.
BY GRAVITATION.		BY PUMPING.	
Kendal	12,029	Clithero	10,864
Lancaster	16,005	Burnley	28,700
Fleetwood	3,834	Haslingden	6,929
Preston	82,985	Blackburn	63,126
Ormskirk	6,426	Heywood	12,824
Wigan	37,658	Rochdale	38,184
St. Helens	18,396	Bolton	70,395
Liverpool and suburbs	600,000	Bury	37,653
		Middleton	9,876
Manchester and adjacent places	600,000	Oldham	94,344
		Macclesfield	36,101
Stafford	12,532	Congleton	12,344
Burton-on-Trent	13,761	The towns and the districts of the potteries	188,083
Tamworth	10,192		
		Lichfield	6,893
		Birmingham and the towns adjacent	573,036
		Hinckley	3,644
		Nuneaton	4,645
		Coventry	41,647
		Rugby	7,818
		Daventry	4,124
		Towcaster	2,715
		Leighton Buzzard	4,330
		Aylesbury	6,168
		Berkhampstead	3,631
		Hemel Hempstead	2,974
		Watford	4,385
Total by gravitation	1,413,818	Total by pumping	1,275,433
		Do. by gravitation	1,413,818
		Total	2,689,251

853. In one item in this table you put Birmingham and the towns adjacent; will you explain what you mean by the towns adjacent?—There are a number of towns in that country, for instance, Walsall, Dudley, Wednesbury, and other towns in the manufacturing district. I put it in that form merely to avoid lengthening the list.

854. I understand you to say that some of those towns may receive their supply by gravitation or by

pumping, either wholly or in part, from the new works Supposing them to want it wholly from the new works, what amount of water are you prepared to give to those towns, a list of which you have handed in?—It is not likely that they would take it wholly, but the capabilities of this project are 350,000,000 gallons per diem, that is to say, 250,000,000 gallons daily for London at a cost of 13,500,000*l.*, and an additional 100,000,000 gallons can be got from Bala and from the district immediately to the north of Windermere and Kendal.

855. We had better deal first of all with the present scheme exclusive of Bala. I understand you to say that this scheme which you have given us now at a cost of 13,500,000 of money, which is to include everything, proposes to give to London a supply of 250,000,000 gallons, leaving 100,000,000 gallons to be dealt with in another manner; would not that be so if you took 250,000,000 gallons for London?—The 13,500,000*l.* is for the supply of 250,000,000 gallons only.

856. Then in the event of your wishing to supply any or all of those towns either in part or wholly, the sum of 13,500,000*l.* would not enable you so to supply those towns?—If the consumption of London increased and came up to 250,000,000 gallons daily we should then have none to spare for other towns, and we should be obliged then to go to additional expense in order to get an additional supply.

857. Then in practice it comes to this, does it not, that if 250,000,000 gallons is required for London you have nothing wherewith to supply any other towns on the road?—Not without incurring additional outlay.

858. And you cannot get the 250,000,000 gallons except you spend 13,500,000*l.*?—Precisely so.

859. How do you propose to give the towns stated in this list a supply of water, either wholly or in part, is it by a supplemental and a different scheme?—In the first place, after the construction of these works, I do not think that the supply of London would jump up all of a sudden from its present amount to 250,000,000 gallons.

860. Could you state to us now what is the amount of the present supply to London?—The present supply to London is about 100,000,000 gallons daily, 108,000,000 gallons I think is the maximum which has been obtained, and I believe, judging from what one sees in public prints, that an additional quantity of about 42,000,000 per day is deemed requisite for the proper dilution of the sewage and the efficient working of the sewers.

861. (*Sir J. Thwaites.*) Are you not under some misapprehension upon that question?—I am only speaking from what I have seen in the public prints.

862. You have made the statement that so many million gallons may be required for the purposes of sewage, that is not so; it is simply a question of ventilating the sewers, and how to get rid of the gases which are generated in the sewers, and if the system of flushing the sewers were adopted it would require such and such a quantity of water, but that is merely speculative; there is no intention whatever of carrying such an arrangement out?—I am only speaking of what I have read.

863. (*Sir B. Phillips.*) If I understand you rightly, your works are constructed to deliver 250,000,000 per day to London, and your present estimate is that about 150,000,000 gallons is all that would be required for some considerable time?—No. The amount of water consumed in London is increasing so rapidly that I believe 150,000,000 gallons would, in a comparatively short space of time, be an insufficient supply for London.

864. How much do you suppose would be sufficient?—Not less than 50 gallons for each individual of the population. In the year 1850 the population of London was about 2,000,000, and the consumption of water was about 44,000,000 gallons per day. In 1856 it had increased to 81,000,000 gallons. In 1865 it amounted to 108,000,000 gallons, being an increase for the whole period of about 4,000,000 gallons daily per annum, and for the latter period about 3,000,000 gallons daily per annum, the individual consumption being then about 36 gallons per day. In 1850 the individual consumption was 22 gallons per day, and in 1865 it had increased to 36 gallons per day.

865. You propose to increase the supply from 36 gallons per head to 50 gallons?—I believe that a less quantity than 50 gallons per individual in a city like London would not be a safe estimate to reckon upon. It is actually now 36 gallons, and then in addition to the increased quantity of water per individual we have to deal with the extraordinary increase of population. In 1850 the population of London was 2,000,000, in 1865 it had increased to 3,000,000, and should it increase in the same ratio for 26 years we shall then have a population of about 5,000,000 of souls requiring a daily supply of 250,000,000 gallons. I take 26 years, because I estimate that the works might and would take probably six years from the time the project received the sanction of the Legislature, and then we should be providing with those 250,000,000 per day for a future not more than 20 years distant.

866. You are dealing now with 250,000,000 gallons for a population of 5,000,000 people, but the question which we want to arrive at in another form is as to what quantity is immediately required, and what the surplus between the quantity required in London and the quantity which you propose to deliver, would be, plus that delivered to those various towns?—I apprehend that for some time after those works were constructed the demand would not amount to 250,000,000 gallons, and that the residue which remained between the consumption of London and the capability of the works might be sold to intervening towns.

867. (*Chairman.*) You stated, did you not, that the maximum supply at present is, 108,000,000 gallons per diem?—Yes, that is 36 gallons per individual.

868. How much additional do you suppose is likely to be required in the space of the next 10 years?—The quantity of water consumed has increased from the year 1850 to the year 1865 at the average rate of about 4,000,000 gallons daily per annum.

869. (*Mr. Prestwich.*) Would it not be better to go back to the year 1830, because from 1850 to 1865 we have been told was an exceptional period, that large works were constructed for the existing waterworks which enabled them to supply that quantity, that is to say, that during those years the supply increased in a more rapid ratio than usual?—I cannot give the statistics from an earlier date than the year 1850, but it is not very easy to put a limit to the consumption of water when it is introduced among a large population, and to give an example of that, between the years of 1850 and 1856 the water supply nearly doubled in quantity.

870. Therefore, that hardly gives the exact ratio of increase?—No, and, therefore, I have taken it over a longer period of time, viz. from 1850 to 1865. The increase in the first six years of that period was at the rate of about 6,000,000 gallons per day, and in the latter period at the rate of 3,000,000 gallons per day. Where water has been introduced into other large towns, for instance, Manchester and Glasgow, it is scarcely possible to put a limit to its consumption when it can be sold at any moderate rate of price.

871. (*Sir B. Phillips.*) Are you aware Mr. Bateman told us that at Manchester they only consume 21 gallons per head per diem?—I do not know what they consume per individual, but I know they consume an enormous amount of water for trade and manufacturing purposes in Manchester. The amount of the public rate levied for water is 16,000*l.* a year, and of the domestic rate 23,000*l.*, the two rates amounting in the aggregate to 39,000*l.* per annum, whilst the amount of revenue derived from water sold for manufacturing purposes is 56,000*l.* a year, so that although they may consume only 21 gallons indivi-

R. Hassard, Esq.

20 Feb. 1867.

dually still there is an enormous quantity consumed for other purposes, for the trading and manufacturing purposes which are incident to any large population.

872. (*Colonel Harness.*) How is the water for manufacturing purposes paid for?—It is paid for at the rate of so much per thousand gallons; in Manchester it is sold for about 6*d.* per thousand gallons, in Glasgow it is sold for about 7*d.*

873. You say that so much is paid for domestic consumption and so much for manufacturing purposes; does the sum obtained from each of the two kinds of consumption give a fair measure of the quantities used in those two ways?—There are two rates levied in Manchester, a public rate and a domestic rate. The domestic rate is levied on house property only, and the public rate is on all property in return for the advantages which an unlimited water supply is supposed to give. The amount of the domestic rate in the year 1865 was 23,000*l.* and the amount of the public rate was 16,000*l.*, making a total of 39,000*l.*, and that was equivalent to a rate of 8*d.* in the pound on all the property in Manchester. There was a revenue derived from the sale of water for public and trading purposes of 56,000*l.*, which went to ease the public rates; the public and domestic rates, if not eased by the sale of water for public purposes, would have together amounted to 1*s.* 7*d.* instead of 8*d.*

874. Do you think that the supply of water for manufacturing purposes was in the same proportion to the supply for domestic and other public purposes as 56,000*l.* to 39,000*l.*?—I cannot tell the quantity used for public purposes there, but it evidently must be very large, because the price is about 6*d.* per thousand gallons, and the revenue is 56,000*l.*

875. (*Sir J. Thwaites.*) I understand that your estimate is 13,500,000*l.* for structural works and other incidental expenses for storing and conveying 250,000,000 gallons daily to the metropolis?—Yes.

876. But it is the case, is it not, that your storing capacity is limited to that quantity of 250,000,000 gallons?—No; the aqueduct is limited to deliver that quantity, but we could store much more.

877. Then your conveying capacity is limited to 250,000,000 gallons?—Yes.

878. Then I see by the list which you have handed in, that you have a population in the several towns of 2,689,251?—Yes.

879. Allowing 30 gallons per head, that would give 80,677,530 gallons per diem?—Yes.

880. Do you think that the supply which the population of London would require for the next 10 years would exceed 150,000,000 gallons?—Yes, I think it probably might at the end of 10 years. I should think that probably 175,000,000 or 180,000,000 would be nearer the mark.

881. Then for the next 10 years the capacity of your supply would be equal to the supply of the metropolis and the several towns enumerated in your list?—Yes.

882. It would be 260,000,000 gallons or rather over?—I think 50,000,000 gallons would go a long way towards the supply of those towns for a considerable period.

883. Then in the event of its being expedient that those several towns as well as the metropolis should be supplied from this source, you would have to give an increased capacity to your tunnels or construct other tunnels?—I shall show the way in which we would meet that. These red districts which you see upon this large map on the wall, you may also see upon the small one, and as the probability is that a great part of the consumption would be in those towns north of Liverpool and Manchester, it would be incumbent upon us either to construct this aqueduct of larger dimensions in the first instance than we have proposed it or to construct a fresh aqueduct for the conveyance of this water to those towns. When the London supply went beyond 250,000,000 gallons, I should prefer constructing a fresh aqueduct from this point (*pointing to the map*) for the supply of those towns.

884. I understood your answer to a question which I put to you, when you were under examination before, to be this, that so soon as the supply of the metropolis would have mastered the capacity of your storing power you would then seek for an auxiliary supply from the Bala lake?—Yes, from the Bala lake and from the red district on the map also. I should say that instead of taking it from the supplementary Westmorland district, in the first instance, immediately north of Kendal, we should take it from Bala, and we should introduce into the aqueduct at Stoke an equivalent quantity of water to that which had been sold on the route of the aqueduct between Ullswater and the potteries district.

885. Did I rightly understand your previous answer that all the water that would be abstracted from your tunnel up to the point of junction at Stoke would be compensated by a supply from the Bala lake?—We could supplement the quantity in our aqueduct from two districts, from the Bala lake and from the district north of Kendal, but we should take it first from the Bala lake.

886. Will you just give us the capacity of the gathering area coloured red?—It is 53 square miles, and that would yield between 70,000,000 and 80,000,000 gallons, based upon the same calculation as the supply from the adjacent district.

887. That red area in point of fact you think would yield a sufficient quantity of water to supply the several towns which you have enumerated in this list, allowing 30 gallons per head per diem?—Probably it would be quite sufficient.

888. But failing that supply, you could obtain a sufficient quantity from the Bala lake?—We could easily bring 50,000,000 or 60,000,000 gallons a day from Bala lake to our main conduit at the potteries and bring it on to London, or distribute such portion of it as might seem advisable in the Birmingham district, taking the residue to London.

889. In constituting that piece coloured red into a gathering ground with a fresh reservoir you would have to make an independent reservoir would you not, as there are no lakes to serve as reservoirs?—Precisely so. We should be dependent upon artificial reservoirs, the sites of which are indicated upon the larger map.

890. Have you formed any opinion as to the additional cost of doing that?—I think that bringing the water from the red district to a point as far south as Liverpool would cost 1,500,000*l.*

891. That 1,500,000*l.* is the cost of forming artificial reservoirs on the ground coloured red and an independent conduit as far as Manchester?—I take it to be the cost as far as the Liverpool reservoirs.

892. You gave us before, did you not, the cost of taking the additional supply from Bala lake?—It is 1,500,000*l.* also.

893. Is there any difference in the length?—Not very much.

894. You utilize the lake in that case?—Yes.

895. And heighten the surface level?—We propose to raise the water 5 feet and draw it off 7 feet below the present surface, which gives us the command of 12 feet, but it could not be raised more than 5 feet on account of the town of Bala and on account of the railway which is being constructed on the southern shore.

896. Having regard to the gathering ground coloured red and its yielding capacity, and also to the supply from the Bala lake, you are of opinion that an ample supply for the metropolis and the several towns enumerated could be obtained?—I have no doubt of it.

897. It is only a question of spending 3,000,000*l.* more?—Yes, 3,000,000*l.* more.

898. (*Mr. Prestwich.*) What would be the additional supply from Bala lake?—Between 50,000,000 and 60,000,000 gallons.

899. (*Sir B. Phillips.*) Going back to the supply of 250,000,000 gallons per day, did I rightly understand your answer to be that in your judgment at the end of 10 years something like 175,000,000 gallons per diem would be a sufficient quantity for the supply of London?—I think that the demand would attain that amount, but whether it would be a sufficient supply or not I am not prepared to say.

900. You have 75,000,000 gallons to deal with?—Yes.

901. Could that 75,000,000 per diem be sold after the rate of 10*l.* per 1,000,000 gallons, which I understand you to be the price to the intermediate towns?—I believe that a considerable portion of it could be sold. I have prepared a table of the rates which would be necessary to be levied in London supposing that no water was sold in the first instance to other towns, and also in the event of such sales taking place, which I beg leave to hand in to the Commission, and it is as follows:—

TABLE showing the relative POPULATION, VALUATIONS, RATES, and INDIVIDUAL CHARGES in Liverpool, Manchester, and Glasgow, as compared with those which would be necessary in London after the introduction of Water from the Lakes at a cost for new works of 13,500,000*l.*, supposing no Water sold in the first instance to other Towns, and afterwards in the event of such sales taking place.

Name of City.	Amount of the domestic rate.	Amount of the public rate.	Equivalent to a rate on all property of in the £.	Amount received from the sale of water for public and trading purposes.	Average annual charge for water per individual of the population.	Rate which would be necessary if not eased by the sale of water for public and trading purposes.	Average annual charge for water per individual, if not eased by the sale of water for public and trading purposes.	Amount of the valuation of house property.	Amount of the valuation of other than house property.	Total valuation.
	£	£	*s. d.*	£	*s. d.*	*s. d.*	*s. d.*	£	£	£
Liverpool, population 500,000 -	25,000	40,000	—	40,000	2 7	—	4 2	—	—	—
Manchester, population 600,000 -	23,000	16,000	0 8	56,000	1 4	1 7	3 2	600,000	600,000	1,200,000
Glasgow, population 400,000 -	48,000	7,000	1 1	35,000	2 9	1 6	4 6	600,000	600,000	1,200,000
London in 10 years, population, say 3,750,000.	833,333	—	0 10	250,000	4 5	1 1	5 1	15,000,000	5,000,000	20,000,000
London, if 25,000,000 gallons of water were sold daily to other towns at 10*l.* per million gallons.	742,083	—	0 9	250,000	4 0	1 1	5 1	15,000,000	5,000,000	20,000,000
London, if 50,000,000 gallons were so sold.	650,833	—	0 8	250,000	3 6	1 1	5 1	15,000,000	5,000,000	20,000,000

I take it that in 10 years from this time the population of London will amount to 3,750,000 people, and that the rateable value will amount to 20,000,000*l.* It is now between 15,000,000*l.* and 16,000,000*l.*, nearly 16,000,000*l.*, and it has increased during the last seven or eight years at the rate of 400,000*l.* per annum, which would make it at the same rate of increase 20,000,000*l.* at the expiration of 10 years. I estimate that no water is sold to the intervening towns in the first instance, but that a revenue of 250,000*l.* per annum is obtained from the sale of water in London for manufacturing and trading purposes, which is less than at the rate which is obtained in Liverpool and Manchester, or Glasgow.

902. (*Sir J. Thwaites.*) Will you tell us the quantity which you propose to supply for this 250,000*l.* What does that 250,000*l.* represent in water?—It would be about 30,000,000 gallons per day. I estimate that the water for trading purposes would be sold at 6*d.* per 1,000 gallons, being about the same price as is charged in Glasgow, Manchester, and Liverpool. 10*l.* per 1,000,000 gallons is what the water would cost when brought to London, and what it could be sold for in bulk to other towns.

903. (*Chairman.*) Do I rightly understand you to say that you expect to receive 250,000*l.* by the sale of 30,000,000 gallons of water per diem for public and trading purposes?—Yes.

904. (*Sir J. Thwaites.*) That gives you 250,000*l.* a year; is that plus the cost of management, or is it the gross receipt, or have you made out a balance sheet showing what the structural cost of your works would be, the quantity of water that you would sell, the rate at which you would sell it, what the cost would be to distribute it, and what the profit would be to a company supposing it were a commercial company?—I have not estimated it in that way, but I have estimated the rate which it would be necessary to levy on all the property in London, supposing the capital borrowed at 4 per cent., that 425,000*l.* per annum is paid to the existing water companies, and that 100,000*l.* is taken as the expenses of management.

905. Is that 425,000*l.* for the use of their distributing power?—It is to continue their dividends, we absorbing all their works.

906. That is in point of fact utilizing the present net work of pipes and arrangements?—Yes and the reservoirs to the utmost extent.

907. Taking possession in fact of all their property?—Yes, and continuing their dividends, which dividends now amount to about 417,000*l.*

908. Do you propose that that should be a continuous dividend?—I have estimated for it as such.

909. You have made no calculation, have you, as to any mode of getting rid of this charge, spreading it over a series of years by adding to the annual payment; providing a sinking fund in fact?—No, I have not.

910. You are to get 250,000*l.* for the sale of 30,000,000 gallons per diem; how are you to pay the 425,000*l.* to the companies?—Out of the rates levied on property; it would require an average rate of 10*d.* in the pound on all property, on the valuation of 20,000,000*l.*; the annual expenses we estimate in this way, 425,000*l.* to the water companies, 100,000*l.* for collection and management, and 540,000*l.* per annum for the interest on 13,500,000*l.* at 4 per cent.

911. What does 10*d.* in the pound produce?—It produces 833,333*l.*

912. What are those various sums added together?—There is 425,000*l.* to the water companies, 100,000*l.* per annum for management, and 540,000*l.* for interest at 4 per cent. upon the capital; those amount to 1,065,000*l.* That rate of 10*d.* in the pound will produce 833,333*l.*, and that with the addition of 250,000*l.* for the sale of water for public and trading purposes, would produce a total revenue of 1,083,333*l.*, being something like 18,000*l.* in excess of the annual expenditure.

913. The amount that you receive for public and trading purposes is over and above, is it not, the rate of 10*d.* in the pound levied over the whole of the metropolis?—Yes, the 10*d.* rate would be necessary after giving credit for the 250,000*l.* received for the sale of water.

R. Hassard, Esq.

20 Feb. 1867.

914. The 10*d.* in the pound would be merely for domestic purposes; it would supply no manufacturing and no public wants of the metropolis in any way?—It would supply every want, except such wants as those of private trade or manufacture; it would supply water for all public purposes.

915. The supply to private trade and manufactures would not be included in the 10*d.*?—No; we estimate the revenue of 250,000*l.* to be derived from the sale of water for the purposes I have mentioned in addition to the 10*d.* rate. The 10*d.* rate includes the whole rate that would be levied; it includes what is generally called the domestic and the public rate, that is to say, there might be a rate of probably 2*d.* in the pound on all property, and a rate of 1*s.* in the pound on the house property, but I have not subdivided it; I have taken it as an average rate over the whole metropolitan area.

916. (*Chairman.*) The 250,000*l.* I presume is for private manufacturers?—Yes, precisely. The 10*d.* rate would cover all the water for domestic purposes, and also for what are called public purposes.

917. (*Sir J. Thwaites.*) You have calculated 30,000,000 gallons as the probable quantity that would be used for trading purposes, the remainder would, I presume, be for domestic purposes, the extinction of fires, and many other purposes of that kind?—For a variety of other purposes.

918. (*Sir B. Phillips.*) You have stated the amount which you deem sufficient to continue the dividends to the existing water companies, and also to pay interest at the rate of 4 per cent. upon the 13,500,000*l.* which you propose to borrow?—Yes.

919. Have you made any provision by which this 13,500,000*l.* is to be repaid?—No, the usual way is that the money for carrying out works of this nature is borrowed upon the security of the rates of the town or district which is proposed to be supplied, and it is levied in the shape of an annual rate. That is the way in which it is done in Liverpool, Manchester, Glasgow, Dublin, and most other large towns.

920. Have you any sinking fund wherewith to repay this amount?—We have not provided it.

921. (*Mr. Harrison.*) Do you know what is the present amount which is paid for water for manufacturing purposes in London?—I do not, beyond this, that it is sold at rates varying from 6*d.* to 10*d.* per 1,000 gallons. The quantity I cannot tell.

922. Can you tell what the gross revenue of all the water companies was in 1865?—I think it was between 700,000*l.* and 750,000*l.*

923. It was 738,000*l.*, and you assume that you would get about 250,000*l.*, or about one-third of the present rate for manufactories and the public?—Yes.

924. Do you think that, at the present moment, anything like one-third is paid for water for manufacturing purposes?—I am not aware. I know that the quality of the water now supplied to London is such as to be unfit for a very great number of manufacturing purposes.

925. You have taken 425,000*l.* as the amount to be paid in dividends, are you aware that in 1865 the amount was 440,000*l.*?—No, I am not.

926. And you do not know what it was in 1866?—No, I do not, but if their receipts are greater, no doubt there would be greater property to represent them.

927. Probably you are not aware that the actual amount of gross revenue was 738,000*l.*, and that the actual amount paid in dividends and interest in 1865 was 440,000*l.*?—I was not aware of the precise amount, I thought it was something like 417,000*l.* or 418,000*l.*

928. Is it not generally understood that in 1866 they have again been increasing their supply and the amount of their dividends?—I am not aware of that.

929. Assuming that to be so, that would, of course, *pro tanto*, alter that portion of your calculations?—Not very much I apprehend, because if their receipts were larger there would be a greater amount of property to represent the increase.

930. You would have to convert that amount into capital, and the 4 per cent., of course, would be upon the larger amount?—No doubt.

931. Then the expenses of management of the present water companies being 288,000*l.* in 1865, you calculate that on this scheme being carried out the expenses would be reduced to 100,000*l.*?—I believe that 100,000*l.* would cover them very amply; their main expenses now are filtration and pumping and the intermittent service, and a variety of expenses of that nature, which would all be done away with.

932. Mr. Bateman calculated that there would be a considerable amount of valuable property which would be realized?—Yes; Mr. Bateman took that into account, but we did not in making our estimate.

933. You merely took it generally that the present cost of 288,000*l.* would be reduced to 100,000*l.* by the new system?—Yes.

934. Can you at all give any detail of that, as to what is the cost of filtration and pumping?—No, I cannot, but I can tell you what is the cost of filtration. I have here extracts from the evidence which was given before the Committee upon the Metropolis Water Bill in 1851 and 1852. For the New River Company, represented by Mr. W. C. Mylne, the cost of filtration was given then as 0·43*d.* per 1,000 gallons; for the Southwark and Vauxhall Water Company represented by Mr. Quick, it was given as one-eighth of a penny per 1,000 gallons; for the Grand Junction Company, represented by the same gentleman, it was given in also as one-eighth of a penny; by Mr. Hawksley, it was given in generally that it varied from one-eighth of a penny to a half penny per 1,000 gallons. On this point I would beg to hand in the following table:—

TABLE showing the COST at which FILTRATION was variously estimated by Engineers of great experience, as extracted from their Evidence given before the Committee on the Metropolitan Water Bill of 1851–52.

Name of Water Company.	Authority.	Cost of Filtration.
New River - -	Mr. W. C. Mylne	·43*d.* per 1,000 gals.
Southwark and Vauxhall.	Mr. Joseph Quick	⅛*d.* ditto.
Grand Junction -	Ditto - -	⅛*d.* ditto.
—	Mr. Hawksley -	⅛*d.* to ½*d.* ditto.

935. You do not at all know what the cost of pumping would be?—I do not know what the cost of pumping actually is. The cost of pumping can be easily calculated, but Mr. Hemans tells me that it is generally estimated at from 80,000*l.* to 100,000*l.*

936. That would get rid of the odd 88,000*l.* in round numbers?—Yes.

937. Then it is easy to calculate what the filtration would cost, assuming that to be so, and putting aside the question of the property saved, what other expenses would there be saved?—There would be a considerable saving, of course, in the number of officers necessary. There would be a considerable saving, first of all in the concentration of management, and next there would be a considerable saving in the number of employés which are now necessitated by the intermittent service system. In collection, of course, there would be a very large amount of saving, because each company now collects for itself, and if it were all concentrated under one board or under one authority it could be done very much cheaper.

938. The whole of those items would be perfectly easily ascertained, would they not, through the companies themselves?—Yes, I should think that there would be no difficulty in ascertaining the amount, or at all events in ascertaining what it ought to be.

939. Your conviction is that 100,000*l.* per annum would be abundant to maintain all the new works which you are going to construct, the 270 miles of aqueduct, the whole of the works of distribution in London, all the expenses of management, all the cost of collection,

and everything in connexion with the scheme ?—I think that would suffice for all.

940. Is that based upon any approximate calculation, or is it an assumption ?—It was roughly gone into, but not more than roughly. The amount of repairs or upholding the works I put at a very light figure indeed, because we do not think that there would be any large annual outlay on that account, or scarcely any.

940*a*. Seeing that between 1857 and 1865 the net amount divided or paid in dividends and interest has increased from 308,000*l*. to 440,000*l*. or more than 40 per cent. in a period of eight years, and that in all probability it would be eight years before the works could be completed, do you assume that in the meanwhile the water companies will stand where they are or that they will go on increasing their works ?—I understand that although of late years they have largely increased their outlay still their annual expenses have been also very largely increased, so that, in point of fact, their dividends remain where they were.

941. Their dividends may remain the same but have they not to pay an additional amount of interest on borrowed money ?—The 425,000*l*. that we have allowed for the dividends to the water companies includes the interest upon borrowed money.

942. I see by the return that while their expenses have increased from 224,000*l*. to 286,000*l*. or 62,000*l*. their net amount of dividend and interest has gone from 308,000*l*. to 440,000*l*., so that, of course, whether it be in dividend or in interest there is a very large and progressive increase in the amount which you would have to compensate them for ?—Yes, but then you would get a much larger amount of property than they possess at present.

943. In making any calculation in the commercial view of the question, would not the value of such property be a very important feature in the calculation ?—Yes, I think so, but I thought it safer to exclude it altogether. We did not know what it was and we did not wish to put anything in the estimate that might be considered problematical.

944. Did you take the same view as Mr. Bateman did, that any scheme of this sort could only be carried out on the assumption that by some Act of Parliament the whole of the water companies were bought up and placed under one control ?—I do not see that any scheme of this nature could be carried out otherwise. It is based upon the supposition that the ratepayers should be the proprietors of their own works and guardians of their own interests, if one may so express it.

945. You have mentioned the works at Aberdeen ; are you personally acquainted at all with the arrangements which are made for carrying out those works ?—I merely mentioned Aberdeen so far as the aqueduct is concerned, with relation to the velocity of the water in the aqueduct. I am not acquainted with the circumstances of Aberdeen.

946. (*Chairman.*) Those works at Aberdeen were I believe only opened last October, were they not ?—Yes, they were opened in the autumn of last year by the Queen.

947. (*Mr Harrison.*) To what extent on either side of your line of aqueduct do you assume that towns will be within reach of your water ?—Liverpool is a long way off, but we pass within a quarter of a mile of the pure water basins of their Rivington reservoirs, consequently we should only have to deliver the water into a pond a quarter of a mile distant from our aqueduct.

948. You take Manchester as one of the towns to be supplied, containing a population of 600,000 people, is not Manchester considered to be one of the towns that is best supplied with water in the kingdom ?—Yes, I believe that Manchester is very well supplied.

949. Perhaps you would hardly include Manchester in the list of your towns ?—Manchester, at present, I believe is extending its works, and it comes to a question whether a town should lay out capital in extending its waterworks or pay a rent for water from an aqueduct passing their doors.

950. In the case of Manchester, they are supplied by a continuous service, are they not ?—Yes.

951. Do you think it at all likely that you would be able to supply them profitably, they having all their works already constructed and water nearly as good as what you could supply them with ?—I do not think it likely that Manchester will take its supply from us, at all events for a long period to come ; but as the area of drainage from which the supply is derived, is comparatively limited, that period, in the event of our aqueduct being constructed, must, sooner or later, arrive.

952. Could Liverpool continue with its present supply, or would they be likely to require yours ?—I will state just what difference it would make to Liverpool. Liverpool has been contemplating of late incurring an outlay of 1,500,000*l*. in order to procure a daily supply of 20,000,000 gallons of water from Bala, of which, in all probability, for 20 years to come they would not be able to use more than 10,000,000 gallons, that is, in addition to their present supply, and the interest of 5 per cent. upon 1,500,000*l*. would be 75,000*l*. a year, and if you add 5,000*l*. a year to that for the cost of management, collection, superintendence, and repairs of permanent works, which is probably the least sum at which you could estimate it, it will amount to 80,000*l*. a year for the supply of 10,000,000 gallons per day. We, passing their works, could supply them with the same quantity of water at 35,000*l*. or 36,000*l*. a year, and we could then supply them with an additional 10,000,000 gallons in 20 years from this time, or at whatever time that supply was wanted. In other words, we could supply them with water at half the money at which they could get it from Bala.

953. Putting Liverpool out of the question, have you considered practically to what distance from your line of aqueduct it would be reasonable to suppose that you could supply towns, would it be within a distance of say 10 or 20 miles ?—I think that 10 miles is an easy and practicable distance.

954. You would probably not go beyond that distance ?—I think not, except in special cases.

955. Therefore you do not by your scheme supply any of those towns which lie on the east of your aqueduct — take Sheffield for instance ?—No, not at all.

956. You omit them altogether, you merely take a band of 10 miles on either side of the line, and take those towns which are practically on the line of your aqueduct ?—Precisely so. All those Yorkshire towns have been omitted, because we know that they can get from districts which are in their immediate vicinity a supply of very excellent water more cheaply than they could get it from the lakes, even if they combined for the purpose. We have therefore omitted them entirely.

957. In that particular district to which you refer as the means of supply for all those towns, is not the water of immense value to those towns for the purpose of manufacture ?—Water in that country is of extraordinary value, pure water especially, for dyeing, bleaching, and chemical operations, and works of that nature for which pure water is so especially valuable.

958. Have you given your attention at all to the question of the saving to the inhabitants of a town from the use of soft water as compared with hard water ?—I can only speak from the opinion of others, not from personal knowledge.

959. (*Sir John Thwaites.*) Do you know the reasons why the municipality of Paris have elected to use hard water instead of soft ?—No, I do not. I do not know whether they have soft water within a practicable distance.

960. They have two sources of supply, one of soft and the other of hard water, and they have elected the hard ?—I know that they have introduced chalk

R. Hassard, Esq.

20 Feb. 1867.

water for drinking purposes, but for what reason I am not aware.

961. (*Mr. Prestwich.*) They gave the preference to the water from a chalk district over the water from a granite and slate district?—I am not aware whether the expense of procuring the water would be the same in both cases.

962. The distance is rather greater for soft water, but not much, it being 140 miles in the one case and from 80 to 105 in the other.—I was not at all aware of the circumstances of the cases.

963. You are aware, are you not, that there is a great difference of opinion with regard to the use of soft and hard water for the purpose of drinking?—There is no difference of opinion in that respect in the north of England, or where soft water has been introduced in towns. Where it has not been introduced I have heard that there has been an opinion expressed against it, but where it has been introduced I never heard of a difference of opinion. I have never heard the superiority of soft water over hard water questioned where it has once been introduced.

964. (*Chairman.*) You consider, do you not, that Mr. Bateman's scheme is open to several objections?—Yes.

965. Is one of your objections to his scheme this, that the results of the rainfall in the district from whence he intends to take his water are not sufficiently known?—Yes, and that they are at variance with the returns of the gauges which have existed in the immediate localities for some period of time back.

966. But by that answer you do not mean that the observations actually taken at the gauges which were quoted by Mr. Bateman were incorrect?—Certainly not.

967. But that the returns from the gauges in the district which he has taken do not tally with the quantities registered from gauges in other parts of the district at no great distance?—That is not quite what I mean. I mean that the deductions which Mr. Bateman has arrived at from the result of gauges kept during the three wettest months of an exceptionally wet year, are not in accordance with the results of gauges in the immediate locality relative to the fall of three dry years.

968. Are you not aware that Mr. Bateman stated that it was not an unsually wet season in that particular district of the country?—Mr. Bateman stated that it was not, but Mr. Symons has informed me that it was a year 17 per cent. above the average, while it was 24 per cent. above the average in the lake district, that being a difference of only about 6 per cent.

969. Mr. Symons does not refer, does he, to that particular district which is alluded to by Mr. Bateman?—He referred to the adjoining locality; he had no returns of gauges except one in the immediate drainage area, but he had several from the localities around, and he informed me that although it was not quite so wet a year there as it had been in the lake district, still it was an exceptionally wet year.

970. (*Mr. Harrison.*) Mr. Symons is now going to look into that question. Have you, yourself, any returns from any of those gauges upon which you base your opinion of the actual rainfall?—Yes, I have. Immediately to the south of the drainage area of the southern portion of Mr. Bateman's scheme, and only four miles distant from it, at the town of Rhayader, there has been a rain gauge kept for the last five years It is situate at a considerable elevation, being at an altitude of 880 feet above the sea. It is also at a point which is peculiarly favourable for the deposition of rain, being open to a valley leading through the hills from the west and being also open to a valley leading through the hills from the south-west, and it is situated at the convergence of those two passes through the hills, and it is, I believe, as wet a place as there is to be found in that locality; and I am corroborated in that opinion by the returns of that gauge of Mr. Bateman's which he placed above Llanidloes on the same hill as the Rhayader gauge, but at a distance of probably six miles from it, and which gave more rain than any of tho other gauges. I will give the returns at the Rhayader gauge. In the year 1863 the rainfall was 42·72 inches; in the year 1864 it was 37·02 inches; and in the year 1865 it was 41·48 inches; being a mean rainfall for those three years of 40·31 inches. There is another gauge kept at Llanidloes which is within the Severn drainage area, but that has only been kept for a short time. In the year 1865 at that gauge, which is about 750 feet above the sea, the rainfall was 43·33 inches, or not much more than that indicated by the Rhayader gauge. So that judging from the returns of those gauges I am of opinion that a greater rainfall than 42 inches could not be reckoned upon in three successive dry years over that drainage area. And I am further corroborated in that opinion by having worked it out by analogy from the same gauges that Mr. Bateman gave in the lake district, and comparing the rainfall for those three months with the rainfall of the year 1865 in the same locality, and reasoning in the same way for the Welsh district, I get a mean rainfall of 41·62 inches.

971. (*Col. Harness.*) Is the Rhayader gauge to which you refer the same as that to which Mr. Symons referred, or a different one?—There is only one.

972. (*Chairman.*) At page 6 of Mr. Bateman's evidence of the 6th of February, in answer to question 23, he says, "At Rhayader which is at the head of "the river Wye, getting into rather more open "country, and which is 880 feet above the level of "the sea, the rainfall was 41½ inches; at Llanidloes, "which is 750 feet above the level of the sea, it was "43⅓ inches; the average of all those figures is 59¼ "inches. Now in order to draw conclusions from "those facts as compared with gauges which have "been kept in other parts of the country, I have taken "nine places as nearly as possible under similar cir-"cumstances, but giving the advantage in point of "altitude to the mountain gauges which have been "kept in the lake district"?—I take those very same nine gauges which he has emunerated and I get a very different result.

973. You differ from Mr. Bateman in the deductions which he draws from those figures?—Yes, entirely.

974. That is one part of the objection which you entertain to Mr. Bateman's scheme; that the information which he has obtained as to the rainfall is not reliable?—In my opinion it is not sufficiently extended to enable a safe deduction to be drawn from it.

975. (*Mr. Prestwich.*) In the only one which you have given us you appear to agree very much with Mr. Bateman?—I agree with him, but that I conceive is the wettest place in the whole locality. The gauge which Mr. Bateman placed between Rhayader and Llanidloes gave a higher return than any other gauge that he had used. You will find in Mr. Bateman's estimate of rain in the Welsh district he gives returns of two gauges, in the one case of 29·80, and in the other of 29·90 inches, that is, out of six gauges two of them represented a very high ratio of rain; that would be one-third of the number of gauges, but the elevated area which these two gauges represent is only about one-fifth of the whole drainage area, so that to take those in the arithmetical mean will not give you a true return. I make the true mean rainfall according to those gauges as 17·34 as against, I think, the arithmetical mean of 18·59 inches.

976. (*Mr. Prestwich.*) Then admitting the gaugings in Wales, so far as we know them, to be correct, upon what grounds do you draw a different conclusion from Mr. Bateman?—Mr. Bateman reasoned that from those returns, compared with similar returns in the lake district, you could reckon upon 48 inches of available rain during a succession of three dry years, and for the purposes of that reasoning he took the returns of these nine rain gauges in the lake district, Keswick, Scaw Fell Pike, Derwent Island, Great End, Brant Rigg, Esk Hause, High Close, Ambleside, Patterdale Hall, and Wastdale Head.

977. (*Chairman.*) Mr. Bateman is asked in page 9, at question 35, "Calculating that you have a

" plus of 48 inches, what will that area yield?—(*A.*) " In my calculations I have not assumed 48 inches, " I have no doubt that I should be justified in doing " so, but I have taken 36 inches." Then at question 36, he is asked, " I understand you to say that 48 inches " is what is available in the Glasgow district?—(*A.*) " Yes, and what would be available in the Welsh " district, because I believe that the rain would be " the same or almost the same, year by year. By " these calculations I think that we should be quite " safe in taking 48 inches as the net available produce " of the water in this district; but in my calculations " I have only taken 36 inches, and that is only three " inches more than we are actually collecting and " delivering in the Manchester waterworks, although " the average rain will probably be 40 or 50 per cent. " more in the Welsh district than it is in the Man- " chester district." You join issue with Mr. Bateman, upon the probable amount of water to be gathered in that district?—I do.

978. That is one objection which you have to his scheme?—It is.

979. Have you any fault to find with the drainage area, either as to its being enclosed or any other reason?—Yes; a great part of the drainage area, probably one half of the entire, is enclosed land, pretty thickly populated, and under cultivation and tillage, and to that cause may probably be attributed the comparatively large quantity of organic matter that those waters contain.

980. Before going into that you say that one half of the drainage area is under cultivation and tillage?—Probably one half.

981. What do you understand by the words " cultivation and tillage"?—Land that has been broken up or is in the course of being broken up, and cultivated; farm lands occupied by farm houses and used for farming purposes.

982. Would you call half the drainage area arable land?—Enclosed square fields with a great deal of arable land, all the valleys cultivated, and some of them highly cultivated.

983. Are we to understand you that half the drainage area is under the plough, or only occupied as farms?—Half of it is enclosed land, and a great deal of that half under the plough, and to that circumstance, I think, may be attributed the comparatively large quantity of organic matter which those waters contain. And I may prelude what I am going to say by stating that samples of water taken from rivers and streams in summer, when there is nothing but spring water flowing down, will not fairly represent the quality of the water which may be derived from the same district throughout other portions of the year. As we get on towards autumn and up to midwinter, when it is about its maximum, the quantity of organic matter increases largely in waters of that kind, and therefore a sample taken in the height of summer cannot be considered a fair sample of water. The increase of organic matter is due to the decaying vegetation of autumn. The presence of organic matter in water is always attributable to decomposing animal and vegetable matter, and it is about the most deleterious ingredient that water can contain; in fact, among chemists water which contains more than one grain of organic matter per imperial gallon is not considered a fit or proper water for domestic use, and waters which are similar in other respects will take their rank in the standard of excellence, in the inverse ratio of the quantity of organic matter that they respectively contain. And having said that I may possibly surprise your Grace and the other members of the Commission if I tell you that water from those Welsh streams when taken in summer actually contains nearly 50 per cent. of organic matter more than the water supplied to London by the water companies at the same period. If you will turn to page 15 of Mr. Bateman's pamphlet you will find the quantity of organic matter there given as being 1·35 grains per gallon. A gallon of water weighs 70,000 grains, and consequently that represents 1·35 parts in 70,000, and that is equivalent to 1·93 parts in 100,000 parts. I now hand in a copy of the Registrar General's Report, dated the 27th of August 1866, in which there is an analysis given of the condition of the waters supplied to London for the previous week. The analysis is by Professor Frankland, and the quantities of organic matter in the waters then supplied vary from 1·80 to 0·89 parts in 100,000 parts, giving a mean of 1·33 parts in 100,000 parts, as against 1·93 parts in 100,000 parts in the Welsh waters, being an increase of organic matter of 0·47 per cent., so that as far as organic matter is concerned the Welsh water contains a much larger proportion than the London water.

The witness delivered in the following table:

EXTRACT from the REGISTRAR GENERAL'S REPORT, dated August 27, 1866. The analysis of waters for the month of August being by Professor Frankland, F.R.S.

Companies.	Number of houses supplied in July 1866.	Average daily supply of water in gallons during the month of July 1866.	Solid matter in 100,000 parts of the waters.	Organic and other volatile matter included in column 4.	Amount of oxygen required for oxidation of organic matter.	Total Hardness.
THAMES:—						
Chelsea	26,463	8,671,600	24·89	1·29	·0344	17·4
West Middlesex	36,000	9,090,414	23·62	1·16	·0304	16·2
Southwark and Vauxhall	73,857	12,180,000	23·66	0·98	·0336	16·2
Grand Junction	25,636	9,800,484	25·00	1·09	·0368	16·8
Lambeth	36,374	9,907,400	25·51	1·53	·0368	17·2
OTHER SOURCES:—						
Kent	33,162	6,791,427	38·88	1·80	·0084	24·8
New River	112,245	25,812,000	20·20	0·89	·0133	13·7
East London	90,174	20,524,883	26·14	1·44	·0328	17·7
South Essex	750	160,000	38·04	1·80	·0108	22·2
			Average	1·33		

984. (*Mr. Harrison.*) The table which you find in Mr. Bateman's evidence does not give 1·93?—1·93 is the proportion in 100,000 parts. He gives the number of grains per gallon at different points in detail, but at page 15 of his report, he says, the " average amount of organic impurity being 1·35 grains per gallon," and I have taken it that the average of the whole is the same as Mr. Bateman gives in his pamphlet, and 1·35 grains per gallon gives us 1·93 parts in 100,000 parts.

985. If you refer to the note to the table on page 13 of his evidence you will see that he excludes that which is the largest source as being an impure water but he includes it in this calculation here?—No, I

R. Hassard, Esq.

20 Feb. 1867.

fancy not, because it would give a very much larger return than 1·35 if that was included. I will now hand in another return of the Registrar General, dated 28th January of this year, in order to show that the organic matter increases considerably in streams and rivers up to mid-winter, when it is at its highest.

The witness delivered in the following table:

EXTRACT from the REGISTRAR GENERAL'S REPORT, dated January 28th, 1867. The analysis of waters for the month of January is by Professor Frankland, F.R.S.

Companies.	Number of houses supplied in Dec. 1866.	Average daily supply of water in gallons during the month of Dec. 1866.	Solid matter in 100,000 parts of the waters.	Organic and other volatile matter included in column 4.	Amount of oxygen required for oxidation of organic matter.	Total hardness.
THAMES:—						
Chelsea	26,783	7,786,200	31·34	2·39	·0532	18·5
West Middlesex	36,331	7,872,706	31·99	2·33	·0532	18·8
Southwark and Vauxhall	73,940	13,130,500	32·42	2·56	·0532	18·8
Grand Junction	26,450	8,650,150	32·82	1·28	·0597	19·4
Lambeth	37,165	8,819,100	31·88	2·32	·0597	19·4
OTHER SOURCES:—						
Kent	33,693	6,149,006	39·40	1·22	·0223	22·5
New River	112,852	21,621,000	31·39	0·69	·0432	19·4
East London	90,174	19,842,000	35·68	2·64	·0727	20·5
South Essex	910	183,497	37·93	3·02	·0140	22·2
			Average	2·05	Being 57 per cent. more than the quantity of organic matter contained in these waters in summer.	

986. (*Chairman.*) What particular stream does the Registrar General refer to in that report?—He refers to all the London waters. I now beg to hand in a table showing the comparative amounts of organic matter in waters from Wales, in the waters now supplied to London, and in waters from the Lakes.

TABLE showing the comparative Amount of Organic Matter in Water from the Severn District—in Waters supplied to London, in January 1867, by the Water Companies—and in Water from the Lakes, the Samples for Analysis having been taken in the Month of January.

Name.	Grains of organic matter in a gallon of water.	Equivalent quantity in 100,000 parts of the waters.	Equivalent quantity in 100,000 parts of the water when taken in winter.	Observations.
Severn waters	1·35	1·93	3·06	With ·57 per cent. added to the quantity in summer, to represent its condition in winter.
London waters	— In winter.	—	2·05	
Lake waters	·58	—	·83	Samples taken in winter.

Consequently, the Severn waters contain about $3\frac{3}{4}$ times, and the London waters about $2\frac{1}{2}$ times the quantity of organic matter present in the Lake waters.

987. Would not the streams in the mountainous districts of the country be subject to a great quantity of the same organic matter coming down in what would be called in the south country the height of of summer; perhaps not to so great a degree as in mid-winter, but very much more than would be the case in the southern part of the kingdom?—No, quite the contrary. In this drainage area, or in the mountainous district at least, only a portion of it is so subject. There is a great portion of the valleys under cultivation and tillage, and the amount of organic matter which comes down in autumn is greater, being then due to the decaying vegetation of the district. In the summer time the amount of organic matter is always less in rivers and streams than it is at any other period of the year.

988. What months do you consider summer months for this purpose?—Say the month of June or July.

989. Are you not aware that in the north of Scotland there are very often considerable floods in the month of May from the snow melting on the hills?—But that does not bring down organic matter; the organic matter is gone. There is scarcely any in such a district. It is bare rock and uncultivated ground; it brings down a quantity of matter in suspension no doubt but no organic matter.

990. When you speak of this district do you mean the Welsh district?—I mean generally a mountainous district.

991. Surely you would not call the Scotch hill district a district of bare rock, from which no organic matter could be brought down?—Very little organic matter comes from such a district; organic matter is due to decaying vegetation or decaying animal matter.

992. Would not streams, which pass over a great quantity of peat, be constantly carrying down organic matter?—Certainly not; that is quite a distinct question.

993. Then would you consider that in a stream which was as pure as crystal in the morning and was more like porter in the evening there would be no organic matter?—It might be quite free from organic matter.

994. (*Mr. Prestwich.*) A peaty solution surely would be organic matter, would it not?—No, it is not due to decomposition in such a case; it is not generally considered in the light in which organic matter is spoken of.

995. (*Chairman.*) Are not those great peat mosses made up from the decay of vegetable matter?—They are not vegetable matters in a state of decomposition; I wish to draw that distinction. They are vegetable matters, no doubt, but not in a state of decomposition.

996. Because they are decomposed?—Peat is an antiseptic; it is one of the strongest correctives of decomposition that we have.

997. It is rotted trees, is it not?—I have repeatedly seen trees which have been dug out of peat bogs, which

have been there for thousands of years, and which were as fresh as possible when dug out.

998. That particular tree might be fresh, but all the matter surrounding it would be in a state of decomposition?—It is not considered so with relation to water.

999. (*Sir J. Thwaites.*) I presume your notion of organic matter has rather reference to the decomposed vegetable matter, the result of manuring?—Precisely; the decomposed vegetable and animal matter.

1000. (*Mr. Prestwich.*) In analysing water you cannot distinguish, can you, whether the organic matter is derived from peat or from decomposing animal matter or vegetable matter?—In any analysis of water that I have seen there has always been some statement to that effect, separating if there is anything due to peat from what is due to decomposing organic matter.

1001. (*Chairman.*) Then I gather that your objection is that the analysis of the water has been made at a time of the year when a correct analysis could not be made?—Yes, and that the water in Mr. Bateman's scheme actually contains more organic matter than the water now supplied to London.

1002. And that the water so analysed, even at a favourable period of the year, as you say, contains more impurity than the water supplied to London at the same period?—Yes.

1003. (*Sir B. Phillips.*) You spoke just now of the increased impurity of water in midwinter, have you any return to show that?—In midwinter there has been no return given of the increase of organic matter in the Welsh waters, but I have handed in a second published return of the Registrar General, dated the 28th of January of this year, in which the mean of the organic matter in the water delivered in London is 2·05 parts in 100,000 parts as against 1·33 parts in the same water delivered in summer, which is an increase of 57 per cent. owing, I have no doubt, to the decaying vegetation of the autumn.

1004. Have you any return of the same period and from the other districts?—I have from our own district.

1005. I mean from the Welsh district?—For comparison with the Welsh district I have added to the Welsh water the same percentage of excess of organic matter which is present in the London waters in winter as compared with the same waters obtained in summer.

1006. That is an assumption, is it not?—Yes, it is an assumption, and in that way we find that in winter the Severn waters would contain 3·06 parts of organic matter in 100,000 parts; that is, with 57 per cent. added to the quantity in summer, being the same proportion in which organic matter in the London waters in winter exceeds the amount in summer. In the London waters it is as I have mentioned, 2·05 parts in 100,000 parts, and in the lake waters which were taken purposely in the month of January, as being the period in which we should naturally expect most organic matter, the quantity of organic matter amounted to ·58 parts of a grain in a gallon of water; that is equal to ·83 parts of organic matter in 100,000 parts, and from this it may fairly be assumed that the Severn water would contain about $3\frac{3}{4}$ times, and the London water about $2\frac{1}{2}$ times, the quantity of organic matter that is present in the lake water.

1007. (*Col. Harness.*) You are assuming, are you not, that Dr. Thomson's analysis was made of water taken in the summer?—It is so stated in Mr. Bateman's pamphlet.

1008. Do you not observe that Mr. Bateman, at page 13 of his evidence, has omitted the Severn water proper?—Yes, it must have been omitted and therefore the impurity comes out less, but there are some other streams which have been omitted which would quite make up the difference.

1009. His average is evidently taken from this table, including the Severn water proper?—But there are some other streams which are not included in that, which would fully make up the the difference I have mentioned.

1010. (*Mr. Prestwich.*) Would you not also consider that the conditions of such a river as the Thames are very different from the conditions of the Welsh streams?—Not in that respect.

1011. (*Chairman.*) What is the formation of the lower portion of the district from which Mr. Bateman gathers his water?—All the lower parts of the district and all the valleys are covered with a dense coating of clay, which is all cultivated. There are one or two exceptions certainly, but generally speaking, almost all the beds of the streams are formed in this dense clay, and a very small amount of rain is sufficient to render them perfectly turbid as I myself saw quite recently. If it is wished I can give the details of the condition of the water in several of these streams after a certain number of hours of rain.

1012. (*Mr. Prestwich.*) The clay of that district is accumulated principally in the valleys, is it not?—Yes, but some of the hills to a considerable height are covered with clay and cultivated, others are covered with clay, and cultivated over the very hill top, and both on the hill sides and in the valleys there is this dense clay.

1013. (*Sir J. Thwaites.*) I presume the cultivation is a question of degree in the higher parts?—Of course, higher up the hills it is mostly slight. The ground is broken up occasionally, but in the lower portions of the district, in the valleys, it is all more or less arable land, and there are some as good farm houses and as fine farmsteadings and buildings there as you will see anywhere in England.

1014. (*Chairman.*) What would be the size of those holdings?—They are fine large farms.

1015. My question had reference to the hilly district in Mr. Bateman's scheme?—The northern district near Llanwddyn is clean good ground, and therefore I wish to except that from the remarks which I now make. All the lower portion, the more southern portion of the district, for instance, near Canoffice, that district is all cultivated land; every one of those names which you see upon the map represents a farm house, or a cluster of houses.

1016. What is the size of those holdings?—I should say that they must be in the low ground probably 60 or 70 acres, or something of that nature.

1017. What would those holdings of about 60 acres represent in rent?—I did not inquire what the rent was, but the land is all very well cultivated, and they are a most excellent class of farmers, but what the rent is I cannot tell.

1018. What would you put it at per acre?—I should say for those farms probably the average rent would be from 1*l.* to 1*l.* 5*s.* an acre. The southern portion I should think would be much more valuable. The site of the Trefeglwys reservoir is covered with very fine farms indeed.

1019. Holding from 60 to 80 acres of land averaging 1*l.* an acre, do they farm very highly?—All the lower portion is very well cultivated.

1020. The land over the hills, I presume, is not broken up?—Over some of the hills in the lower portion it is tilled and enclosed to the very hill top, especially in the southern and eastern parts of the drainage areas.

1021. (*Sir J. Thwaites.*) You mean that they are pasturage?—They are pasturage and broken up, and relaid with artificial grasses. In the north-western portion, the Llanwddyn portion, there is a good deal of hilly ground, and therefore my remarks do not apply to that portion.

1022. (*Chairman.*) The ground would be broken up every two years?—I cannot say that, but it is repeatedly broken up. I may mention that I am just now told by the gentleman who was down with me that he made inquiries at Garthbibio and at Trefeglwys, and was informed that the rent at Garthbibio was 30*s.* an acre, and at Trefeglwys it was about 2*l.* an acre, but that was the best class of land.

1023. That would not range over a very large district, those would be exceptional prices, I presume?—Yes, in giving an estimate of the rent I gave 1*l.* to 1*l.* 5*s.* as the general rent.

R. Hassard, Esq.
20 Feb. 1867.

1024. I assume some sheep walks would not let for over 2*s.* 6*d.* an acre?—A considerable portion of the north-western part near Llanwddyn is sheep walks, and I presume that that land would average about 2*s.* 6*d.* an acre. There is peat in that locality. There are some extensive grouse shootings there. Lord Powis has some very large grouse shootings there.

1025. You say that the clay causes the streams to become turbid in a very short time?—Very turbid.

1026. Have you any objections of a particular nature connected with factories to the southern portion of this gathering ground?—There are two woollen factories in that district, above the points at which the water is proposed to be abstracted. There is one above Llanidloes and another in the district draining into the Tylwch river south of the Llanidloes, those are flannel manufactories.

1027. (*Sir J. Thwaites.*) There are no dyes used in that manufacture are there?—No; there is a great deal of wool washing, but I am not aware as to dyes. I should imagine not, as it is the native flannel.

1028. (*Chairman.*) Would a woollen manufactory, such as you describe, have any effect upon the water?—Wool-washing, which is largely carried on, is certainly not a matter which would improve the water. But there are only two woollen manufactories, and they are a small matter compared with a large area.

1029. In fact, you do not lay any stress on the woollen water?—No.

1030. (*Sir J. Thwaites.*) The water is used merely to wash out the oily matter, is it not?—Yes, I believe that is the process.

1031. (*Chairman.*) Do you consider that in this district it would be necessary to have those works connected with filtration?—Yes, undoubtedly; in the southern portion of the project it could not be avoided, in the northern portion it possibly might.

1032. Will you first explain why that could not be avoided in the southern portion?—In order to avoid filtration and to adopt the separating system, as is practised at Manchester, it is necessary to have two reservoirs, an upper and a lower one. When the water is turbid it is allowed to pass on into the lower reservoir, and it is there impounded for compensation, and when it is comparatively pure it is turned into the upper reservoir, and there stored for the town's supply; but you will perceive that in the southern portion of the scheme there is only one reservoir, because the smaller ones proposed on the Clywedog river and on the Tylwch river, the last-mentioned of which, however, could scarcely be made as a railway occupies the valley, are so small, compared with the large reservoir, that they would count for nothing, and therefore you will find that the water both for supply and compensation, and whether turbid or otherwise, must be stored in Trefeglwys reservoir, and that would render filtration absolutely indispensable in my judgment. The separation system could not there be practised.

1033. Do I rightly understand you to state that one place which was contemplated by Mr. Bateman for a reservoir is a place in which he could not put one?—Yes, the district south of Llanidloes, in which Mr. Bateman states, that the sites for the reservoirs have not yet been surveyed; reservoirs could not be made, because the valleys which are available for that purpose are now occupied by railways.

1034. Have you any idea how it is that Mr. Bateman proposes to put a reservoir in a place where he must know that he could not do it?—The railway may not have been opened, or Mr. Bateman may not have been aware of its existence at the time he surveyed this country. It is the Mid-Wales Railway, and it has been opened, I think, about 12 months.

1035. (*Mr. Harrison.*) The construction of that railway has been in operation for the last six or seven years, has it not?—I am not aware of that.

1036. (*Chairman.*) Would you not have thought that from Mr. Bateman's connexion with engineers he must have known of that?—All I can say is that there is no site available for the construction of a reservoir in that district, except valleys traversed by railways. The level of the rails is only a few feet above the water surface, and the river is crossed in several places by the railway. I have here a letter which I can put in if necessary, from the agent of the contractor who constructed that railway, which will corroborate what I say, that the railway crosses the river in several places.

1037. (*Mr. Harrison.*) I think that Mr. Bateman stated that he had not specially surveyed that portion of the district, but that from his general knowledge he had no doubt that sites might be obtained?—I examined the locality and I could not find any sites worth speaking of, except those in valleys which are already occupied by railways.

1038. (*Chairman.*) Do you consider that this particular district is full of metalliferous veins and mineral workings?—Yes, I do. In Mr. Bateman's pamphlet, he states that the district is free from metalliferous veins or other sources of objection, and I heard him make a similar statement in this room, and I can only say that some great oversight must have occurred, for it is not only full of metalliferous veins, but it abounds in mineral workings. There are no less than five lead mines within the drainage area of the southern portion. On the river Clywedog, about a mile and a half above Mr. Bateman's proposed reservoir at the village of Stay-a-little, there are two large lead mines and works draining into the river; one of them, which is called the Deliffy, is the richest mine in that country, it employs about 220 hands, and it is provided with washing and crushing machinery, and all the necessary adjuncts. About half a mile from that mine, higher up the valley, there is another lead mine and works called Dwngwm mine; it is not so extensive a mine as the first one, it occupies about 110 hands.

1039. (*Sir J. Thwaites.*) Are those mines worked by means of water power or steam?—The machinery is worked by water power, at least I was told so. I was not down close to the mine, but I was told so. On the river Afon Biga, draining into the river Clywedog, there is another lead mine and works, but what number of hands they employ or the extent of that mine I cannot tell you, because I forgot at the time to make inquiry into it, but it is indicated on the Ordnance sheets as a lead mine and works apparently as extensive as the other two which I have mentioned. Close adjoining the proposed reservoir at Stay-a-little there was a mining level being driven with the prospect of another mine being opened up. On the river Ceryst, at the upper end of the proposed reservoir at Trefeglwys, there are two lead mines, one of them is called the Van mine, it belongs to Earl Vane; it employs about 120 hands, and the mine is situated at the very water's edge. The mine is in a locality where it would be almost impossible to get rid of the drainage without pumping it away, it is likewise fitted with extensive washing and crushing machinery, and is worked by water power; immediately opposite to that, on the south side of the valley, there is another lead mine, which has not been worked for some years, but I was told that it was in contemplation shortly to reopen it. There are lead mines and works also in the vicinity all round, and in the northern portion of the drainage area, near Can-Office, a place was pointed out to me where a vein of copper has been recently opened, and which is said to afford a promise of success. In order that the question of the existence of the lead mines might not be dependent altogether on testimony, I have brought up from the Van mine immediately adjoining the upper end of Mr. Bateman's proposed reservoir at Trefeglwys, some specimens of ore (*producing a specimen*). This is the ore after it has been crushed and washed (*producing another specimen*). I also brought up with me a sample of the water taken from the river Ceryst, about half a mile below the point where it receives the drainage of the Van mine (*producing the same*). The river was a considerable stream. We have minerals in our district, but not to anything like the extent of this.

1040. Are there any lead mines in the northern

portion of the district?—There is a lead mine in the adjoining valley near the town of Llangynnog. It is not within the gathering area, but it is within the district which Mr. Bateman pointed out as the area to which he could extend his works, if necessary.

1041. (*Mr. Prestwich.*) In his evidence at page 11, Mr. Bateman mentioned the existence of lead mines in this district, but he did not think that that would affect his water as the water from those mines could be diverted?—I am speaking from his pamphlet in which he states, certainly, that there are no metalliferous veins within the districts from which he proposes to take water.

1042. At page 11 of his evidence, in answer to question No. 137, he says, "The 1·96 includes what "was coming down from lead works worked in that "valley, and which I have consequently rejected. "There are two or three mills there, and also the "sewage of Llanidloes, and therefore that 1·96 ought "not to be taken as a test"?—Mr. Bateman has mentioned that those mineral workings are on the river Severn, which he proposes to exclude from the scheme, but the lead mines and works which I have spoken of are not on the river Severn, and Mr. Bateman in his pamphlet certainly states that the districts he has selected are free from metalliferous veins.

1043. (*Mr. Harrison.*) He mentions, does he not, his taking water at Llanidloes bridge where there are some lead works?—That is the river Severn, which he proposes to exclude from the scheme.

1044. (*Chairman.*) You think that his project could not be extended, supposing that a larger area were required and the demand for water increased, as the district to the north-east of his scheme is highly cultivated and there are lead mines and mineral workings in the valley traversed by the river Tanat?—Yes; that is what I have shown the Commission on the map.

1045. And you think that it could not be extended in a southerly direction to the district bordering on the river Wye, because the valleys there also contain lead works and are occupied by existing or authorized railways, which would preclude the construction of reservoirs?—Yes.

1046. What objection have you to the sites of the proposed reservoirs?—I object to the sites of those reservoirs, first of all on account of the great destruction of property which would necessarily ensue. They contemplate altogether the submergence of nearly nine square miles of cultivated and populous country; for instance, the Llanwddyn reservoir in the valley of the Vryny, would cover 1,000 acres. That is the least valuable land of the whole; but it would submerge the entire village of Llanwddyn, containing from 30 to 40 houses with its church and adjoining graveyard, two Methodist chapels, and several detached farm-houses and cottages. The first reservoir on the river Banw just above Can-Office would cover 800 acres of valuable land and would submerge the village of Garthbibio with its new and handsome parsonage and schools attached, two Methodist chapels, and many detached farm-houses and cottages.

1047. Can you state the population of those two villages?—I cannot give the population, but the first village contains from 30 to 40 houses, and the village of Garthbibio contains, I should think, probably 30 houses. The second reservoir on the river Banw, just below Can-Office, would cover 600 acres of valuable land.

1048. In those two villages, one containing from 30 to 40 houses, and the other containing 30 houses, all the houses would be covered with water, would they not?—Yes, they would be all submerged. The great reservoir on the rivers Ceryst and Tarannon at Trefeglwys would cover 1,600 acres of valuable and highly cultivated land, and would submerge the entire village of Trefeglwys, containing probably 40 houses, with its recently newly re-erected church, the adjoining graveyard, the parsonage, two Methodist chapels, one of them having a small graveyard attached, and many valuable farm-houses and cottages. And most of these reservoirs would submerge the main lines of turnpike and other roads through their respective localities, as well as the various properties which I have just mentioned. And all those reservoirs are formed in clay valleys, and the sides are, for the most part, flat and sloping. If the water were to be preserved pure in them it would require an immense expenditure of money in artificially beaching them. They would have to be covered all over with stone, otherwise the wash of the water in those large reservoirs on the clay sides would keep the water perpetually turbid. I saw an instance of that recently in the Roundwood reservoir near Dublin, which was a small reservoir compared with these, covering only 420 acres, it has, however, flat clay sides, and the wash of the water on them was keeping the water in the reservoir quite turbid.

1049. (*Mr. Prestwich.*) I think that Mr. Bateman stated that there was only one of the valleys in which there was any large amount of clay?—There is plenty of clay for puddling, and the material is very admirable for that purpose. I also wish to state, with relation to these reservoirs, that from some observations which I made in the locality, I have reason to think that some of them, at all events two of the largest the reservoirs, one at Garthbibio, above Can-Office, and the large reservoir at Trefeglwys, will not contain nearly the amount of water at which their capacity is estimated. I think that some error of computation must have crept into the calculations. I may be wrong of course, but the result of my observations was to lead me to believe that those reservoirs would not contain nearly the amount of water which was mentioned in Mr. Bateman's paper.

1050. (*Sir J. Thwaites.*) Have you calculated the cubical contents?—I have not calculated the cubical contents myself, but I have satisfied myself that the dimensions and depth of water in those reservoirs could not be such as he says.

1051. (*Mr. Harrison.*) Have you had sections made of them?—No.

1052. You will recollect that I asked Mr. Bateman the question whether those calculations were based on actual survey, and that he said that as regards the reservoirs, they were entirely so?—Your question, as I understood it, was whether there was a section taken on the line of the embankments.

1053. You will not find that I refer to the line of the embankments; it was intended to be a general question?—That was my impression.

1054. (*Colonel Harness.*) What was the nature of your observations?—My observations were made with a very excellent aneroid barometer, it being perfectly steady at the time, and under such circumstances you could read within 5 feet with the greatest ease.

1055. (*Sir J. Thwaites.*) Have you any doubt as to the stability of the dam which Mr. Bateman proposes?—The localities are such that embankments could be made there perfectly well.

1056. (*Mr. Harrison.*) You stated, did you not, that you do not think there is any possible means of adding to the area from which water could be obtained?—Yes, I have made a statement to that effect.

1057. Did the possibility ever occur to you of putting a drift-way through to the west side of this watershed?—Yes. The whole of the western slopes of those hills are a mass of metalliferous veins and workings, and, therefore, I believe that no water fit for use could be obtained from that district. It is a notorious fact, that the whole of the western slopes of those mountains are covered with lead veins and lead works. You may see in this green area on the map that the mineral veins protrude into the drainage areas of several streams on the eastern side of the hills. It is there that those lead mines, which I have mentioned, occur.

1058. Excepting on that ground there would be no difficulty at all in doing it?—No.

1059. (*Chairman.*) Have you made any calculation as to the comparative cost of the water delivered in

R. Hassard, Esq.

20 Feb. 1867.

London between Mr. Bateman's project and your project?—Yes, I have prepared a table to that effect.

1060. Will you state shortly to the Commissioners the heads of that table?—I have added to the cost of Mr. Bateman's project in comparing it with ours what would be the annual cost of filtration capitalized, and what would be the outlay necessary for the construction of filters to put the two projects on terms of equality; and I estimate the cost of procuring 220,000,000 gallons daily from Wales, taking the total cost of that project, at 21,000,000*l.*; that is including 8,500,000*l.* for the purchase of the existing water companies' works and interests, and adding 1,500,000*l.* to Mr. Bateman's estimate, which would represent nearly the cost of the filters, &c., added to the cost of filtration capitalized at 20 years purchase, the water would then cost, delivered in London, 95,454*l.* per million gallons daily. From the lakes, if we delivered 250,000,000 gallons daily in London, our capital would be 22,000,000*l.*; adding as before 8,500,000*l.* to the 13,500,000*l.* of our gross outlay; that would bring the cost of water delivered in London to 88,000*l.* per million gallons. Then as our project is capable of bringing in 30,000,000 gallons a day more than the Welsh one, I take it that we deliver 220,000,000 gallons daily in London, and that we sell the other 30,000,000 gallons on the road. And supposing, in the first instance, that we sell 20,000,000 gallons daily at 10*l.* per million gallons, that would reduce our total outlay to 20,540,000*l.* A revenue of 73,000*l.* so derived from the sale of the water I have capitalized at 20 years purchase and deducted from the 22,000,000*l.*, which would be our gross outlay. That would bring the value of water delivered in London to 93,363*l.* per million gallons. Then from the lakes, supposing that 30,000,000 gallons were sold to other towns at the same rate, that would reduce the outlay to 19,810,000*l.*, and the cost of the water delivered in London to 90,045*l.* per million gallons as against 95,454*l.* from the Welsh district.

With the permission of the Commissioners I will hand in the following tables:—

TABLE showing what would be the Comparative Cost of procuring a Supply of 220,000,000 gallons of Water daily from Wales, and of 250,000,000 gallons daily from the Lakes, including the purchase of existing works, supposing, in the first instance, that no water is sold from the lake project to the intervening towns, and secondly, supposing that the 30,000,000 gallons of water which it is capable of supplying in excess of the Welsh project is so sold.

District.	Gallons daily.	Total cost.	Cost per million gallons daily.	Observations.
		£	£	
From Wales - - -	220,000,000	21,000,000	95,454	Cost of filters and filtration capitalized, taken at about 1,500,000*l.* and purchase of existing works at 8,500,000*l.*
From the Lakes - - -	250,000,000	22,000,000	88,000	Purchase of existing works taken at 8,500,000*l.*, and also in the following case.
From the Lakes, supposing 20,000,000 gallons sold daily to other towns at 10*l.* per million gallons.	230,000,000	20,440,000*	—	* A revenue of 73,000*l.* capitalized and deducted from gross outlay of 22,000,000*l.*
From the Lakes, supposing 30,000,000 gallons sold daily to other towns at 10*l.* per million gallons.	220,000,000	19,810,000†	—	† A revenue of 109,500*l.* capitalized and deducted from gross outlay of 22,000,000*l.*

TABLE showing the Gross Cost for Water which has been incurred in Liverpool, Manchester, and Glasgow, including the purchase of existing works, as compared with that which would be incurred in London for a new supply from the Lakes.

	Gallons daily.	Cost.	Per million gallons daily.	Observations.
		£	£	
In Liverpool - - -	16,500,000	1,900,000	115,115	
In Manchester - - -	25,000,000	1,500,000	60,000	
In Glasgow - - - -	27,000,000	1,600,000	59,260	
Ditto, when full supply is obtained from Lough Katrine.	53,500,000	1,800,000	33,645	
In London, with water supply from the lakes.	250,000,000	22,000,000	88,000	Purchase of existing works taken at 8,500,000*l.* and also in the two following cases.
In London, if 25,000,000 gallons were sold daily to other towns at 10*l.* per million gallons, the revenue so obtained capitalized and deducted from outlay.	225,000,000	20,175,000*	—	* Revenue capitalized 1,825,000*l.* and deducted from 22,000,000*l.*
Ditto, if 50,000,000 gallons were sold in same way.	200,000,000	18,350,000†	—	† Revenue capitalized 3,650,000*l.* and deducted from 22,000,000*l.*

Perhaps I might be allowed to observe that if the Commission decide on making a personal examination of these localities (and I scarcely see how a satisfactory solution can otherwise be arrived at), and as the waters to be derived from both districts are essentially flood waters, it would be almost necessary that such an investigation or examination should take place in weather that was moderately wet.

LONDON AND PROVINCIAL WATER SUPPLY. LAKE PROJECT.

ABSTRACT ESTIMATE OF WORKS FOR SUPPLYING 250,000,000 GALLONS DAILY.

Reservoirs, conduits, and works of collection	£1,013,000
Tunnel under Kirkstone Pass: 2 miles at 80,000*l.*, 4 miles at 50,000*l.*	360,000
Aqueduct to London	9,806,260
Regulating Reservoirs at Edgware	500,000
	£11,679,260
Interest on borrowed money and expenses during and attendant on construction	1,820,740
	£13,500,000

ESTIMATE FOR RESERVOIRS AND WORKS OF COLLECTION.

3½ miles of open conduit from Coopers Green to Swindale at 4,750*l.* per mile	£16,625
2⅔ miles of open conduit from Swindale to Haweswater at 5,400*l.* per mile	14,175
Haweswater Reservoir	73,500
4 miles of open Conduit from Haweswater to Heltondale Beck at 4,000*l.* per mile	16,000
Sluices and weir at Askham	5,000
5 miles of open conduit from river Lowther to Pooley Bridge at 7,500*l.* per mile	37,500
1½ miles of open conduit, from Ulleswater to Dacre Beck at 5,000*l.* per mile	7,500
Ulleswater Reservoir	100,000
7½ miles of open conduit from Barrow Beck to Thirlmere at 6,000*l.* per mile	45,000
2 miles of Tunnel on ditto 10ft. × 10ft. at 26,400*l.* per mile	52,800
Thirlmere Reservoir	83,000
Conduit to Ulleswater 5 miles at 7,500*l.*	37,500
7½ miles of Tunnel 12ft. × 12ft. at 30,000*l.*	225,000
10 miles of catchwater drain from Thirlmere to Borrowdale, averaging 2,500*l.* per mile	25,000
⅓rd mile small tunnel 8 ft. × 8ft.	7,500
4¼ miles of catchwater drains from Thirlmere to Easedale Tarn, averaging 2,500*l.* per mile	10,625
2 miles small tunnels, 6ft. × 6ft.	21,120
St. John's Beck compensation reservoir	45,000
Carried forward	£822,845

Brought forward	£822,845
Works for diversion of mining drainage	35,000
	857,845
Contingencies 10 per cent.	85,784
	943,629
Martindale and Swindale auxiliary reservoirs, including contingencies, if hereafter required	69,371
	£1,013,000

HAWESWATER RESERVOIR.

370 acres of land at 75*l.*	£27,750
Rebuilding houses, &c.	6,000
4 miles of new road alongside lake, at 2,000*l.*	8,000
Embankment, 127,500 cubic yards, to cover puddling, pitching, soiling, &c., at 2*s.*	12,750
Waste weir	3,000
Eduction tunnel, pipes, valves, gauges, &c.	16,000
	£73,500

THIRLMERE RESERVOIR.

400 acres of land at 75*l.*	£30,000
Rebuilding houses, &c.	8,000
2½ miles of new road at 2,000*l.*	5,000
Embankment, 150,000 cubic yards, to cover puddling, pitching, soiling, &c., at 2*s.*	15,000
Eduction tunnel, pipes, valves, gauges, &c.	25,000
	£83,000

ULLESWATER RESERVOIR.

76 acres of land at 80*l.*	£6,080
4 miles raising and altering roads at 2,500*l.*	10,000
Embankment at Eusemere Hill, to cover pitching and puddling 10,000 cubic yards at 4*s.*	2,000
Pipes, valves, syphons, and eduction apparatus	60,000
	£78,080

Say 100,000*l.* to cover damage and compensation.

R. Hassard, Esq.

20 Feb. 1867.

The witness withdrew.

Adjourned to to-morrow at 11 o'clock.

Thursday, 21st February 1867.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND IN THE CHAIR.

Sir JOHN THWAITES.
Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

THOMAS DALE, Esq., examined.

T. Dale, Esq.

21 Feb. 1867.

1061. (*Chairman.*) You are, I believe, a civil engineer?—I am.

1062. And the engineer to the Corporation Waterworks of Hull?—I am.

1063. And you have turned your attention, have you not, to the general question of the supply of water?—I have.

1064. You have, I believe, prepared a scheme for supplying the towns of Lancashire and Yorkshire with water from the lake districts of Cumberland and Westmoreland?—I have.

1065. Has this scheme been under consideration by you since the end of 1865?—It has, and for *several years* previous.

1066. Before going into the question of the amount of the supply, what, in your opinion, is the quality of water most desirable for the supply of large towns?—Soft water.

1067. How would you define soft water, or is there any means of defining it?—It is generally by engineers called soft water up to about four degrees of hardness; some admit six degrees of hardness, but I should call it soft water up to and including four degrees of hardness.

1068. Then any water in which there was upwards of four degrees of hardness you would consider as hard water, and not desirable for the supply of towns if other could be obtained?—I should.

1069. You state that you prefer water to be soft for the use of the populations in towns generally, will you give the Commissioners your reasons for preferring soft water to hard?—For domestic purposes, in

T. Dale, Esq.
21 Feb. 1867.

the first place, there is a very great saving in the use of soap; for instance, I will take a chalk water of 17 degrees of hardness, which is about the number of degrees of hardness that the water at the present time supplied to the town of Hull is; a degree of hardness according to Clarke's test is one grain of chalk to a gallon of water. The quantity of soap necessary to soften, say one degree in 100 gallons of water, would be equal to about two ounces, that is to say, about 2 lbs. 2 oz. of soap would be required to soften 17 degrees of hardness.

1070. That is to say, it would take that amount of soap to bring 17 degrees down to four degrees?—No, down to 0, or, in other words, in 100 gallons of water it would require 2 lbs. and 2 oz. of soap to reduce water of 17 degrees of hardness down to distilled water.

1071. That is your first reason, that soft water produces a saving in the quantity of soap used for all domestic purposes?—Yes, that is for washing purposes. Then again in the use of water for making tea and coffee also there is a great saving effected, but I am not prepared to say to what extent.

1072. (*Sir J. Thwaites.*) Has your attention been turned to the saving that would result in culinary operations generally?—It has not; I can only say that it is admitted that there is a great saving. Soyer had some statistics on the subject, with regard to the boiling of vegetables, which I have seen but I have forgotten them.

1073. (*Sir B. Phillips.*) Have you taken brewing into consideration at all?—No, I have merely looked at the matter generally, but there is a great saving in the matter of brewing.

1074. Have you any idea as to what the saving is?—I am not prepared with statistics. The only data on which I have to go in looking at this matter are the calculations and figures which were gone into by Mr. Bateman at the time that the Loch Katrine water was introduced into Glasgow. According to Mr. Bateman there was a saving in the first year of some 36,000*l.* through the use of the soft waters of Loch Katrine (they being something over one degree of hardness,) over the use of the Clyde water of seven degrees of hardness. And in looking just casually at this point I have taken that fact as an inducement in presenting my scheme to the various corporations to induce them to adopt it, and to attract the attention also of manufacturers. I have taken the population of Glasgow at 400,000; Mr. Bateman has gone into the matter very carefully, and he has shown that there was a saving of 36,000*l.* a year upon a population of 400,000 persons. He says, "This was by the substitution of water of one degree of hardness as "compared with the water previously used from the "Clyde, which varied from seven to nine degrees of "hardness." Then let us look at the different manufacturing towns, such as Leeds, Bradford, Wakefield, Dewsbury, Halifax, Huddersfield, &c., where worsted, cloth, stuff, silks, bleach works, dye houses, and other descriptions of manufactories exist so extensively, and where immense sums of money are expended annually in the softening and neutralizing process of the waters at present used by the use of large quantities of drugs and chemicals. By substituting this soft lake water in lieu of the waters at present used, which range from seven to 14 or 15 degrees of hardness, there would be an immense saving of, I assume, upwards of 200,000*l.* annually. But I consider that there would be three times the amount saved in adopting this water for those different purposes, even in a manufacturing point of view. That can only be gone into by obtaining the necessary statistics, which I have applied for in one or two instances, but having been called upon so quickly by this Commission I have not been able to get them together.

1075. (*Sir B. Phillips.*) The districts through which you propose to bring water are the manufacturing districts of Yorkshire, are they not?—Yes.

1076. And you have spoken of certain manufactures there, but your figures are assumption only, are they not?—Nothing more.

1077. You are aware, are you not, that in this district there is a very large number of spinners who use considerable quantities of water in washing their yarns?—Yes.

1078. Has that at all attracted your attention in any way?—I include that in the worsted manufacture, but I have not gone into detail in those matters; I have not the statistics.

1079. (*Sir J. Thwaites.*) Has your attention been turned to the dyeing department of industry, as to the fact of soft water being very superior to hard water?—I have had some conversation with dyers on the subject, and I know that it is most important to dyers; they produce, I understand, a more brilliant colour.

1080. But you have personally no experience upon that point?—No, I have not. Then again, with regard to cloth, I have inquired among the cloth manufacturers and I find that in dressing the cloth the soft waters give a better finish to the cloth than hard water.

1081. (*Sir B. Phillips.*) Your evidence simply goes to this effect, that soft water for all manufacturing purposes is much more desirable than hard water?—That is so.

1082. But you are not in possession of any statistics as to facts?—I am not.

1083. (*Mr. Prestwich.*) Are you aware that when some years ago the question of hard and soft water was discussed in Lyons the dyers there gave the preference to waters containing a very large proportion of carbonate of lime, that is to say very hard water?—I am not aware of that.

1084. (*Sir J. Thwaites.*) In your district is not the manufacture of cloth very extensive?—Not in Hull, but in Yorkshire it is very extensive indeed.

1085. Is the scouring process carried on by means of soap, or how do they get rid of the oil from the cloth?—I am not aware; I am not acquainted with the cloth manufacture.

1086. They use a great deal of oil in the manufacture which must be washed out?—Yes, it must be washed out with soap.

1087. Then the question of hardness or softness would be an element of great consideration, would it not, to the manufacturers of cloth?—Very great.

1088. (*Chairman.*) What is the amount per head per day that you would consider a proper quantity for the population which you are contemplating supplying?—I have put down about 90 gallons per head, not including trade purposes; that is to say, in carrying out the whole of the scheme, speaking prospectively.

1089. My question is, what amount of water do you think each individual would consume or ought to consume?—Allowing for domestic purposes, I put down 20 gallons per head.

1090. (*Sir J. Thwaites.*) Is the plus 20 up to 90 for manufacturing purposes?—In dealing with the whole of this scheme I propose to construct works looking prospectively to the advance of the populations and the requirements of future populations. The total then, according to the works which I propose to be constructed, is 90 gallons per head, looking forward to a further period of, say, 50 years.

1091. (*Sir B. Phillips.*) You mean, do you not, 90 gallons per head upon the present population?—Yes; take 90 gallons per head upon the present population, looking forward to the advance, the quantity of about 20 gallons per head would be allowed in, say, 50 years time.

1092. (*Sir J. Thwaites.*) Have you taken that as the basis of your calculation?—I have.

1093. Do you calculate the prospective increase of the population for any given number of years?—I have taken the matter roughly out.

1094. And does your scheme provide for the increased population of 50 years?—Yes, for 50 years or beyond. (The total population is about 1,500,000.)

1095. Taking a mixed population, a considerable amount of consumption for domestic purposes and a reasonable amount for trade purposes, what in such a case would be your view of the quantity per head ?—30 gallons per head.

1096. What is the quantity which you are supplying to the inhabitants of Hull ? — Including trade and domestic purposes about 32 gallons per head.

1097. Are most of the houses supplied with water in Hull ?—All the houses are supplied with water.

1098. Are not several of the courts there supplied with stand cocks, the water not being laid on to the individual houses ?—The whole of the houses are supplied with water, but in courts the mode is to put stand pipes and the parties go to the stand pipes and draw their water.

1099. Take a court, for example, of 40 houses, I presume the water is not supplied to every house, but they have one common source of supply at the head of the court which all have a right to resort to ?—Yes, that is the plan in some of the courts.

1100. Then the consumption per head of the inhabitants of those 40 houses must be considerably under 20 gallons per head, must it not ?—Taking the average the people inhabiting courts use a great quantity of water. When there is a stand pipe open to children with people going to it from time to time there is more leakage with a stand pipe in a court than there would be if there was a tap at each house a the water taken inside, and therefore I should say that they use on an average as much water as in the houses where the pipes are laid on direct.

1101. Have you tested that by comparison ?—I have not, that could only be done by fixing a meter.

1102. Is it the habit of the landlords in Hull to go on giving an independent water supply to the houses, or is that system of supplying from one source a large number of houses continued ?—Only in courts where there are some 10 or 20 houses ; if it is a large court there are two pipes laid down, for instance, there is a stand pipe and tap put down to perhaps three or four houses, and there is another tap for three or four others, and so on.

1103. Are the houses in Hull, other than those in courts, supplied independently ?—They are supplied independently ; pipes are put in the service pipes, and those pipes are taken in direct into the houses.

1104. Have they cisterns or have they a constant supply ?—A part of the town has a constant supply, and the other part a constant and intermittent supply.

1105. What are your reasons for having part constant and part intermittent ?—The river Hull divides one portion of the town from the other, the one lying to the eastward and the other to the westward, the greatest population is to the westward and includes the old town. The pipes which were laid to the eastern district were put in a better condition from time to time so as to bear the night pressure of the constant supply ; whereas the pipes are more dilapidated on the western side, and we are at the present time taking up the old service pipes and putting in new ones in the different streets and in those cases we adopt the constant supply and the night pressure is left on.

1106. Are we to understand that you have had no reason, other than the insufficiency of your plant to stand the pressure, why you have not a constant supply all over the town ?—That is the case.

1107. And we are also to understand that you are in course of arranging a constant supply all over the town as you are relaying fresh pipes in lieu of those of insufficient strength to resist the night pressure ?—Yes, we are.

1108. Have you experienced any inconvenience arising from the constant supply ?—None at all ; far from it ; there is far less leakage I should say, and I have tested it in fact. I should say that on the eastern portion of the town there is a saving of 25 per cent., or say 20 per cent. to be on the safe side, in the leakage, compared to what there is on the other side of the town.

1109. Is that due to the constant pressure and the the absence of cisterns with ball taps, or is it due to the extravagant escape in consequence of the imperfect plant which you have on the other side of the water ? —It is due to one or two causes, and I may perhaps state them. In the first place, in the intermittent, if any water is wanted in a house the servant goes to the tap and turns it on, and leaves it so, and when the supply turncocks have shut it off at night, perhaps the tap is turned and left open ; in the morning about 6 o'clock the turncocks turn on the water and the people perhaps do not require it until 7 or half-past 7 o'clock for breakfast, and the taps are left running and great quantities of water run away in that way. There is a great loss of water on that account, whereas on the other side of the river, on the eastern portion where the constant supply is on, when they turn the tap and draw water, for convenience sake they shut it off again when they have got their water.

1110. Have you tested by any meter the result of this constant supply as compared with the intermittent system ?—I have tested it not by meter but in this way. We have large Cornish engines at the works, and the water is pumped into the mains at a pressure varying during the day from 60 feet to 110 feet. The works are on the western side of the river Hull, and the principal main proceeds from the works for a distance of some 200 or 300 yards, say 200 yards, and ono branch then passes right away to supply the western portion, and the other one at once crosses the river Hull to supply the eastern portion, and we have two sluices fixed, so that we can shut off the eastern portion of the supply at any time, or we can shut off the western portion and leave the eastern portion on. Then in order to test this I have shut off the west side of the town when the engine has been working say at a certain speed, with a pressure equal to some 60 or 70 feet, and with a draught on both lines of main for both sides of the town. Then when we shut off the western portion we have a certain number of manufactories using a certain quantity of water, and so much for domestic purposes. We then take the inhabitants that are on the southern or the western side, and compare the quantity of water supplied to them with the quantity of water pumped by the engine for the eastern side by itself. Then we shut off the eastern side and make the same comparison on the western side, and the engine gives another result with the same pressure of water in the mains against the same numbers of inhabitants, and making due allowance for the quantities used in trade, and the result shows at once what the saving is by the constant system as compared with the intermittent system, which I say is 20 per cent.

1111. Have you had any complaint from the inhabitants with regard to the change of system ?—The inhabitants are continually crying out for a constant supply, they prefer it to intermittent.

1112. Have you observed or has any officer connected with the corporation reported to that body as to the result upon the public health by the removal of the ordinary receptacles for water and adopting the constant supply ?—That had not been gone into, but there are many objections to the intermittent water supply. When you have a constant supply in the town the mains are continually charged with water, but I have observed that when you have an intermittent supply, when the water is abstracted and run completely out of the pipes a certain vacuum is produced in the pipes and something must rush in to fill it. The taps which are generally fixed for domestic purposes are fixed invariably over sink stones. Then with regard to the pipes themselves, if a leakage takes place in the pipes the water generally oozes through and comes to the surface, and you can discover it and you immediately make good the joint and stop the leakage ; but there are instances, and many to my knowledge, which will occur whenever pipes and services are laid, where the joints have to cross sewers or to come very near places where there is loose materials round the sewers and in the passage of the pipes over those parts leakages will

T. Dale, Esq.

21 Feb. 1867.

occur and the water runs away down the sewers, and you cannot discover the leakage.

1113. Does leakage occur more under the system of a constant supply or under the system of an intermittent supply?—It occurs more with the intermittent than it does with the constant supply.

1114. Is that one of the results that give you the 20 per cent. saving?—It is one of the results. What I wish to point out is this, that after the waters have rushed out of the pipes which have been leaking during the day, the foul gases in the sewers and the foul gases over the sinks rush into the pipes, and are absorbed into the vacuum.

1115. Have you any special arrangement with regard to your watercloscts under the constant supply system?—None in Hull; there is no charge for watercloscts.

1116. In adopting the constant system you must have a distinct arrangement from that which is usual where the water is contained in a cistern; do they use cisterns for watercloset purposes, or have they simply an ordinary pipe to turn on and off?—They use cisterns, and the cisterns are fixed over the watercloscts as before.

1117. Is the use of cisterns general?—It is general for watercloscts.

1118. Would there be no means of getting rid of those cisterns, or, if so, would that tend to waste, do you think?—If you get rid of the cistern you must convey your water with a tap over the watercloset, and if you do that you then have a direct communication when the water is off for the gases of your watercloset to rush up your pipe into the pipe which is supplying the watercloset; but if you have a tank above, that tank provides at once, by the ball tap, a means of protecting the mouth of the feeding pipe to the closet.

1119. A pipe charged with water would not admit the gases which you refer to?—No, but those pipes are shut off occasionally for repairs.

1120. (*Chairman.*) You have given us your opinion, and stated the reasons why you think that the water supplied to the populations of towns should be soft, and of course of the greatest possible purity; it is scarcely necessary for me to ask you that which I suppose all people are agreed about, that in order to ensure this the gathering grounds must be free from all impurity, and be protected against all agricultural and trade pollutions, and especially the sewage of towns?—That is so, of course.

1121. And would you also think it desirable that there should be an unlimited abundance of supply?—Yes.

1122. As large a supply as you can get over and above what you want to abstract at the present time?—Yes, it is desirable on several accounts. In the first place, as regards cleanliness, I think the desirableness of it was proved in the first and second reports of the Commission of 1844 and 1845, before whom evidence was produced to show that from the economizing of water in filthy courts and alleys from people washing their clothes twice over, and from the miasma arising from stopped up drains and choked up sewers, for want of flushing, considerable disease and death were occasioned.

1123. When you speak of economizing water, what do you mean by that expression?—Where towns are invariably short of the quantities required to be supplied, the waters are economized by intermittent supplies; they supply a certain quantity perhaps for a few hours of the day for the use of the inhabitants.

1124. Do you mean that the water used gets very dirty, whereas if they had a cheaper supply they would use more of it, and therefore it would be cleaner for domestic purposes?—Yes, that is what I mean.

1125. When you say that they washed their clothes twice over, you mean that they use the same water twice which they would otherwise use but once?—Yes.

1126. Can you give us your views with regard to what the description of the gathering ground should be?—My views on that subject are these. Mountainous regions, such as those gathering grounds which I propose should be utilized, namely, the Cumberland and Westmoreland lake districts, are fit for no other purpose than as gathering grounds; they can be made no use of by the agriculturist nor the manufacturer; they are mostly bare rocks that are well adapted for gathering grounds. Gathering grounds, under other circumstances, are generally chosen by towns in the immediate localities of the towns, and they monopolize the waters of a district which should be used for agricultural and manufacturing purposes.

1127. Are we to understand you to state that on the grounds which surround Ullswater and which surround Haweswater, which is the district from which you propose to take your water, there is no agricultural population?—Very little, excepting by the sides of the lakes. There are a few farms by the sides of the lakes, and there is some little pasture land there, but very little. The rest is covered with heath and moss and bare rocks.

1128. Would not the heath and moss which you state are there be likely to produce organic impurities in the water?—I should say not.

1129. Do you think that that which is commonly called in those countries moss water is not necessarily an impure water, although it may be a dark coloured water?—There has been a difference of opinion, I think, upon that subject.

1130. What is your opinion as to the quality of the water which would be collected from a peaty and moss district?—I should call peaty water impure water, and I should say that portions of organic matter would be found in peaty water.

1131. And as such injurious to health?—Yes, injurious to health to some extent.

1132. Do I understand you that this ground of Haweswater and Ullswater, which you intend to utilize for the purposes of your supply, is a peaty and moss district in any part of it?—I believe there are some small portions on Bampton common that are peaty, but peat, in my opinion, under some circumstances, and in some positions, is not so injurious to water falling upon it as in other positions. If you have a boggy low district where the waters lie and stagnate, they soon become impure when brought in contact with bog or peat under such conditions; but where the peat lies on a precipitous area, or the waters are continually passing off and discharging themselves, the peat itself is soon cleansed of its organic matter.

1133. On what description of ground in the area from which you propose to take the water does this peat lie?—I have not noticed particularly. I have not looked into the matter in detail sufficiently to answer the question.

1134. Have you made any personal inspection of the ground which you have marked upon your plan as the ground from which you intend to take the water?—I have.

1135. But not sufficiently accurately to state which part of it is peat and which is not?—No, I have not. I speak of it generally.

1136. (*Mr. Prestwich.*) In your pamphlet you give an analysis of the lake water by Professor Way, which apparently is the same analysis as he furnished to Mr. Hemans. Have you had any independent analysis made of those waters?—No, we have taken them as good soft waters.

1137. (*Sir J. Thwaites.*) Do you state that you have walked that district?—I have been in that district.

1138. And you think that on Bampton common there is peat?—There is some little peat there.

1139. Is there not a very large tract of peat there going down towards Bampton?—I have not noticed it so as to speak to the quantity.

1140. Did you notice in going over Martindale common a tract of peat?—There are some portions

dotted round there, but I have not gone into the matter sufficiently to notice as to the quantity.

1141. But you walked over it, I suppose, for the purpose of ascertaining whether it was a proper gathering ground for your water?—Yes, I have gone over the whole district, but not so as to enable me to speak, except generally.

1142. (*Chairman.*) But as to the quality of this water, which you say is good soft water, and the sort of water which you desire to get, you have taken that, as you say, from the returns furnished to Mr. Hemans by Professor Way, and you have assumed all that is so stated to be correct?—Yes, so far as this analysis goes, but I consider that it is a soft water. This analysis of Professor Way's was taken evidently under certain circumstances, and not at a favourable time, and I simply inserted it in my second address to the governing bodies of towns in order to induce them to go there. I may observe that I have taken the matter up simply at my own expense, and as expressing merely general views. I have not had sufficient time to mature them, neither could I afford to do so as a private individual, therefore I have approached the subject as near as I possibly could with certain data with a view to induce those governing bodies to go to the lake district for their water supply. But I was about to state that I assumed, first of all, before this analysis was taken, that those waters were equal to the Loch Katrine water in softness without going to the expense of an analysis.

1143. What grounds had you which induced you to assume that the waters proposed to be taken from Ullswater and Haweswater were of the same quality as the Loch Katrine water?—Because the gathering ground being composed of the lower silurian rocks, when the rain fell on them there would be no mineral impregnation to harden the waters, and they would be as soft as the Loch Katrine waters.

1144. (*Mr. Prestwich.*) They are very similar gathering grounds, are they not, as far as regards the geological structure of the country?—Very similar.

1145. (*Chairman.*) Have you anything to state to Commissioners upon the failure of the sources of supply to various towns?—It is some 15 years ago since this idea first entered my head as to supplying towns with water from mountainous districts, and especially from Westmoreland and Cumberland, and my attention was drawn to it from the continual demand made for water and the insufficiency of the water supplied to different towns. I may point out, first of all, the supply to Liverpool as a failure; up to 1850 the water supply of Liverpool was in the hands of several companies, and was derived from the new red sandstone. In that year the waterworks were purchased by the corporation, who felt desirous of extending their works. They were presented with three different schemes: one was by Mr. Hawksley, the Rivington scheme; the second one was by Mr. Newlands and Mr. Simpson, who went for an extension of their present source from the red sandstone supply; and the next one, which no doubt was the best, was by Mr. Rawlinson, who proposed the Bala lake. Those schemes were referred to Mr. Robert Stephenson, who held a court of inquiry; he made a series of experiments and received a large mass of evidence, and the council on this report determined to carry out the works at Rivington.

1146. The Commission do not wish to inquire into the various schemes which have been before the public for the supply of Liverpool; we will take it as a matter of history that Liverpool is supplied now from a certain district?—I want to show the failure both in quantity and quality. The Pike scheme was to have supplied 25,000,000 gallons per day, and the pumping was to be done away with, and the amount that was expended was one and a half millions of money, but that quantity has not been supplied, and the quality has not been desirable, and therefore that source has failed. I have statistics to show that if necessary.

1147. What you mean is that in those towns which were proposed to be supplied from districts near to them, the supply has not kept up to the demand, and that therefore you would wish to go to a larger area and a mountainous district, where you think the supply would be so to speak unlimited?—That is my view of the case; Leeds is in the same position, and in that case the water supply there has failed in quality. The Pollution of Rivers Commission, I think, have had evidence sufficient to show Leeds does not suffer from quantity; they have power to pump 6,000,000 gallons a day from the river Wharfe.

1148. And you are of opinion that the mountainous districts of Cumberland and Westmoreland will supply both the quantity and the quality that are necessary for all those towns which are now not supplied in a satisfactory manner, some as regards quantity and quality?—That is my view of it.

1149. (*Sir B. Phillips.*) How is Halifax supplied at this moment?—Halifax is supplied from gravitation from catch water areas in the locality, I think, from the millstone grit.

1150. (*Chairman.*) You object also, do you not, to supplies from rivers and streams, because they are open to pollution as they pass through the country?—Yes.

1151. And you propose to get your water from Ullswater and Haweswater?—I do. (*The witness exhibited plans. See Appendices Q (1) and Q (2).*)

1152. Ullswater being 477 feet above the Ordnance datum, and Haweswater 694 feet?—Yes, those are the levels.

1153. And your scheme proposes to supply water to 20 towns of Lancashire and Yorkshire to the amount of 131,000,000 gallons a day?—Yes, for domestic purposes, taking the population at about 1,500,000.

The following is a list of the towns, and the quantities which my scheme proposes to supply:—

	gallons.
Lancaster	2 millions.
Preston	8 ,,
Wigan	4 ,,
Dewsbury	3 ,,
Wakefield	3 ,,
Liverpool	40 ,,
Leeds	15 ,,
Bingley	1 ,,
Kendal	2 ,,
Bolton	8 ,,
Blackburn	6 ,,
Keighley	2 ,,
Bradford	10 ,,
Huddersfield	4 ,,
Burnley	4 ,,
Rochdale	4 ,,
Halifax	4 ,,
Colne	1 ,,
Bury	8 ,,
St. Helen's	2 ,,
	131

1154. And you also propose by the same scheme to supply many small towns and districts contiguous to your main trunk pipes, over and above those which you have given in that list?—I do.

1155. And do you also propose to give to the whole of those towns water for manufacturing purposes?—I do.

1156. What is the amount of water which you propose to abstract daily from the lake districts?—The pipes that I propose are intended to have capacity of discharge at the rate of 150,000,000 gallons per day, and I deal with it in this way, I propose to raise Ullswater 10 feet above its present level.

1157. How do you purpose to raise it?—By a dam at the foot at Pooley bridge, by doing so I should impound an extra quantity over and above what is in the lake at its natural level of 7,985,000,000 gallons, then if I lower the lake from its present level, at five feet, which is the depth at which I propose to draw off the water, that would produce 2,915,000,000 gallons; affording when the lake is raised 10 feet above its present level or total storage of 10,900,000,000 gallons. Haweswater I propose to raise by an embankment 30

T. Dale, Esq.

21 Feb. 1867.

feet, and that would impound an extra quantity of 4,100,000,000 gallons by a dam at the Lowther end.

1158. (*Sir J. Thwaites.*) Before going from Ullswater, you propose, you say, to raise it 10 feet, have you carefully examined the banks of the lake?—I have looked round the banks of the lake, but I have not made a survey of it.

1159. Do you not know that the western shore is studded with houses of very great value; I mean the upper part towards Patterdale?—I believe there are houses there.

1160. You would flood them by raising the lake 10 feet, would you not?—Some of them would be flooded, but not many; I have not made a survey so as to be able to state the number of houses or the value of the property; I have not gone into that question so far. In going into this matter, I have gone into it simply generally just to show the feasibility of the scheme.

1161. A part of a feasibility of a scheme would be its reasonable cost, would it not?—That I am prepared to show, because I have allowed liberally in the estimates.

1162. But you have not made an estimate at all have you for the destruction of property in Ullswater?—I have allowed a sum for contingencies in which I have included roughly the value of the land and the cost of removing a number of houses.

1163. Surely this is not a contingency, it is a substantial part of the scheme when you are flooding houses and property to the extent that you are in this case?—In going into my estimate I have allowed roughly for the value of lands, and the moving of houses, and the contingencies arising out therefrom.

1164. Is that result based on anything like a minute calculation of the value of the property which you do affect?—It is not.

1165. Then what is it worth?—It is impossible in approaching a scheme of this sort to go into minutia.

1166. But as an engineer you usually add a certain sum for contingencies; that is to say, a sum which will cover matters over which you have no control and which you cannot at the time foresee; but here you propose to raise the surface level of the lake so as to flood and destroy a large quantity of valuable land and very many valuable houses, and yet you have made no estimate of the cost of it?—For that and other matters I have allowed a certain amount which I have put together in a lump-sum. I have not gone into the minutia, such as the taking down of houses and removing them.

1167. Then you are not at present acquainted with the number of acres that would be flooded by raising the surface of that lake 10 feet?—I calculate that there are some 300 acres which would be submerged.

1168. (*Mr. Harrison.*) What is the amount which you have allowed in your estimate for those contingencies?—I have put them in with the towns connexions and the works at the lakes at an amount which works out roughly at 255,000*l.*

1169. (*Mr. Prestwich.*) What is the extent of the drainage area of Ullswater itself and of Haweswater also?—The catchwater area of Ullswater is 39,680 acres, including the area of the lake, which is 2,142 acres. The Haweswater catchwater area, including the becks and streams, is 24,320 acres, including the area of the lake, which is 330 acres.

1170. (*Sir J. Thwaites.*) You propose do you not to raise Haweswater 30 feet in level?—I do.

1171. Are you aware that there is a discharge into the upper part of Ullswater of slate washing?—I am aware that there is at Glenridding.

1172. How do you propose to deal with that?—I have thought of that subject and my first idea was to intercept those waters, carrying them into the river Eamont below the foot of the lake, but on more maturely considering the question there is only one way to deal with it if it is to be adopted as a public gathering ground, and that is, the lead mines ought to be purchased. In fact, my own view is that the whole of the gathering ground ought to be purchased, and that no lead mines should be worked in the neighbourhood.

1173. That is not a part of your estimate, I presume?—No, that is not a part of my estimate, but only my view.

1174. (*Chairman.*) That is to say, if a perfect scheme for a perfect water supply to the towns of Lancashire and Yorkshire were to be carried out there would follow a necessity for buying the whole of that country?—I should recommend that the whole of that gathering ground be secured and guaranteed for all time to come against mining or any other purpose of that nature, either by purchase or by lease or by some other mode.

1175. What sum of money would purchase 62 square miles of land, or 70,000 acres?—At the present time the owners are receiving very little from that property, it is only used for game, it is fit for nothing else.

1176. In some portions there are lead mines which we assume to be valuable; have you estimated their value at all?—I have not made any estimate, but those are my views.

1177. I do not mean a close estimate, but have you turned over in your mind what would be the probable or possible cost of buying 62 square miles at Ullswater and 38 square miles at Haweswater, making upwards of 100 square miles?—I have not.

1178. Would not the feasibility of a scheme very much depend upon what it would cost?—Of course.

1179. But if in order to make this a perfect scheme the necessity would follow of buying this land, the purchase of 100 square miles would come to something very large, and the value of the water would be very much enhanced by what you have to pay for the ground, would it not?—Perhaps I may be wrong in going so far as to recommend the purchase of the whole area of the gathering grounds, but if they are adopted as gathering grounds, and I do not know where the towns can get water from elsewhere, a more economical means might be adopted by securing those gathering grounds from being used for lead mining, or if lead mines are searched for and worked there, proper means should be adopted for carrying away the refuse waters used at those mines, either into the river Eamont or to some other place, so as to keep the water from polluting the reservoirs of that lake or the ground around it.

1180. That is to say, you think that Parliament should step in and say either that no lead mines should be worked within an area of 100 square miles, or that the water used in the lead mines should be carried into other rivers—but then, what would become of the people who lived on the river Eamont and those other rivers and who might have property there?—There is the difficulty I grant.

1181. Do you think it right that Parliament should step in and say, that no pollution from the lead mines shall be put into Ullswater or Haweswater, but that it shall all be carried into and convert the river Eamont into a sort of common sewer of the district?—I do not think that that would be right.

1182. (*Sir J. Thwaites.*) How are the people at Penrith to get their supply?—They would pump the water into the town. I said that the present lead mines ought to be purchased and that Parliament should step in and grant powers such as to prevent all future working of lead mines, the waters of which would find their way into the river Eamont; in fact, the lead mining should be stopped altogether.

1183. (*Chairman.*) Supposing I had property in that district, would it not be rather arbitrary in Parliament to step in and say, "You shall not work your "mines, you may have there valuable property which "might produce you thousands and thousands a year," and we say, "You may stay above ground and do "what you like, but you must not dip into the bowels "of the earth to extract that which would be a great "benefit to you and a source of advantage to the "public"?—There is no doubt at all that looked at in that light the matter would seem unjust.

1184. But do you not think it would be unjust?—It would be unjust unless you had a proper compensation for it, but this is the position. Here are towns wanting water—there is no means of supply for them in the localities in which they exist, they have already exhausted their sources of supply, as in the case of Bradford, where you see the reservoirs on the map—they have already exhausted every local supply, and in time they will want more water. Where are they to go to? There is no other place than the Cumberland lakes and that district. And then again there has been an enormous amount of money spent from time to time in those towns in endeavouring to get water in their various localities. Bradford for instance spent some 30,000*l.* or 40,000*l.* in going to Parliament to increase their supply of water.

1185. (*Sir J. Thwaites.*) Has your attention been directed to the question of setting tanks, and to the possibility of precipitating a good deal of mischief which now discharges into Ullswater from the lead mines or the slates?—It has not; but I feel satisfied that the deleterious qualities of lead water cannot be extracted by passing through settling tanks or even by filtration.

1186. You mean that which is held in solution?—Yes, what is held in solution cannot be extracted.

1187. But that which is held in mechanical suspension you can precipitate can you not?—Yes, but with regard to that which is held in solution, there are no means that I know of of extracting that from the water.

1188. Have you had any experience in the filtration of that class of water?—I have not.

1189. (*Col. Harness.*) Have you any idea of the value of the lead mine that is now working at Glenridding?—I have not.

1190. (*Chairman.*) You propose, do you not, to raise the level of the water in Haweswater 30 feet by a dam across the lower end?—Yes, and that would submerge about 273 acres of land in Mardale.

1191. If the whole of the surface of the lake is to be raised 30 feet, how are the sides of the lake to be protected?—The sides are precipitous all round, except at the top part; there is some flat land along the margin of the lake and there are some small cultivated plots at the south end.

1192. In order to give you an additional surface over the whole lake of 30 feet, if the south end of it is flat you would have to raise the north-east end of it a good deal above 30 feet, would you not?—No, in order to get the storage that I require I should raise the north-east end 30 feet and that would submerge about 273 acres of land.

1193. What effect would that have upon the present surface of the lake; how much deeper in fact would the lake be than it is at present?—It would be 30 feet deeper than it is at present.

1194. I understand you that the south end is flat?—It is comparatively so.

1195. (*Sir J. Thwaites.*) On that side of the lake where you see "Haweswater" written on the plan, are you aware that there are farms and houses from one end to the other up to Mardale?—Yes, there are.

1196. It is a small tract of land is it not between the lake and the more mountainous part of the district?—Yes, it is a narrow strip of land.

1197. That would be submerged would it not?—I believe it would.

1198. You would have to purchase that should you not?—Yes, that is included in the 273 acres.

1199. At the Mardale end you would submerge a very large tract of flat land leading up to the Dun Cow inn?—Yes, I think that is the name of the inn.

1200. Have you made any calculation as to the compensation that would be required?—I have put it roughly down under the item of town connexions and works at the lakes.

1201. But you have made no special valuation of the property which will be affected by your scheme?—No, nothing but roughly looking at it.

1202. Have you made any calculation as to the cost of the dam?—Only a rough calculation. I have not made a survey of it nor a cross section.

1203. Have you made no sections?—I have made no cross sections at all of the lakes.

1204. Are the Commission to understand that your estimate is merely a rough estimate?—It is a rough estimate; no estimate can be made but an approximate estimate, unless cross sections and surveys are made and working drawings, the same as if the work was fully gone into. If you have the data on which to base the estimate well and good, but all other estimates are approximate only.

1205. You propose a dam of 30 feet high at the southern end of the lake, surely you can make an estimate of the cost of that dam?—That is included in the other items, but I have not the details as it was not a matured scheme. I did not suppose that I should be asked those details, and I have not them with me.

1206. You propose do you not to take the water from Ullswater round by Clifton and the valley of the Lune?—My proposition is to bring the water first by Clifton and the Cliburn valley

1207. You take your supply from Haweswater and you form a junction south of Clifton?—I do.

1208. And you proceed by an open cutting I presume until you get past King Meaburn to Crosby Ravensworth?—Yes, it is open cutting as far as the trenchwork goes.

1209. Then you have to tunnel, have you not, through Orton Scar?—Yes.

1210. I see that there are alternate lines in your plan at that point, do you propose to carry two tunnels throughout?—No, there are separate schemes. In my first proposal I proposed simply to have one tunnel, the water being brought from both lakes to supply those towns and the tunnel would admit of the water coming from Ullswater, and the tunnel at that level would be some five miles in length; but afterwards in looking at it in order to induce some of the Yorkshire towns alone to take the water and to cheapen the scheme by a shorter tunnel, I proposed to take the whole of the water for the Yorkshire towns from Haweswater alone and to bring it through a shorter tunnel, and the easternmost tunnel is the one which I have marked to show the plan.

1211. Do you know the condition of the rock in Orton Scar?—It is a slatey rock, something like the Welsh rocks at Penmaenmawr and Penmenback.

1212. Have you examined that rock?—I have.

1213. It is a very hard limestone rock, is it not?—It is a very hard rock similar to the rock which was passed through at Penmanback. I was engaged on that tunnel.

1214. What is the length of your tunnel from Crosby Ravensworth to Tebay?—The one for bringing the combined waters of Ullswater and Haweswater would be about five and half miles in length; the other tunnel which is proposed to be made for the waters of Haweswater alone would be three miles in length.

1215. (*Col. Harness.*) Do you keep the pipes separate so as to have the head of the Haweswater water separate?—Yes, there will be a separate head all under pressure.

1216. (*Sir J. Thwaites.*) You take advantage of the elevation of that district?—Yes.

1217. In point of fact you would have two tunnels, or do you propose to bring your pipe through one?—If the Haweswater plan is adopted alone and the Ullswater plan rejected, then I adopt the shorter tunnel, but if both lakes are taken, then the long tunnel of five and half miles would be constructed.

1218. Then those pipes taking the water from Haweswater would be under considerable pressure?—They would if I want to turn the waters of Haweswater upon those towns. I shut off the water from Ullswater by a sluice cock lower down at the junction near Clifton, and I turn on the higher pressure from Haweswater for those towns which are of the highest altitude.

T. Dale, Esq.

21 Feb. 1867.

1219. Then you come out near to the Tebay station?—Yes.

1220. And you then follow the course of the Lancashire and Yorkshire Railway?—Yes, down the valley of the Lune.

1221. (*Chairman.*) What is the size of your pipe?—The pipes vary according to the velocity of the flow and the conditions under which they are placed; they vary from five to seven feet. I may observe that I have furnished also a longitudinal section, showing some of the gradients, but that longitudinal section has been plotted from the contoured lines of the Ordnance sheets, and it is only an approximation. When I first proposed this scheme some 15 years ago, and even since that time, I met with a great many objections and difficulties in getting the scheme before the public in consequence of the continued statements of engineers opposing the scheme, that it was impracticable to carry out the work in consequence of tunnels which would have to be made, some 23 miles in length, and in order to convince the governing bodies of the towns and to meet their objections I drew an approximate section of the surface of the ground as far as Leeds, which is the most difficult part of the ground, with a view to show that the scheme was feasible.

1222. Do you propose to work this tunnel which you state is five and a half miles in length and through very hard limestone from one face or from two faces, or do you propose to sink shafts?—In working that tunnel I propose to sink two shafts, as well as to work it from both faces.

1223. Do you know the depth that you would have to sink those shafts?—No, I have not gone into that, at least I have not the details with me.

1224. Do you know what time it would occupy to drive that tunnel?—The five and a half miles could be driven in from two and a half to three years.

1225. You would depend, would you not, upon the number of faces that you had?—Yes, it would depend upon the number of faces, that is to say, and by sinking down two shafts and working from both ends we should have six different faces to work at.

1226. In all your shafts you would have to blast every inch, would you not?—Yes, every inch would have to be blasted. I have had a great deal of experience in tunnelling. Formerly I was engaged in railways, and I was engaged in the construction of the Penmaenback tunnel in North Wales, which is through a similar description of rock, and I know the number of yards or feet that can be done by the headings of the main tunnels through that description of rock.

1227. (*Chairman.*) Your pipes I think you stated were from five to seven feet in diameter?—Yes.

1228. At this particular point, Tebay, what is the size of your pipe?—According to the flatness of the gradients the pipes increase in size, at Tebay the pipe would be seven feet.

1229. (*Sir J. Thwaites.*) How many pipes do you propose to lay down?—Four lines of pipes, of seven feet. I may state that I propose to take four lines of pipes as far as Leeds, and from Leeds to Bolton three lines of pipes, and from Bolton to Liverpool two lines of pipes.

1230. (*Col. Harness.*) Of those four, how many are from Haweswater and how many from Ullswater?—Haweswater would join on to those four lines at the junction near Clifton.

1231. (*Chairman.*) How many pipes would you take from Ullswater to the point of junction with that which comes from Haweswater?—I should take two pipes from Haweswater and two from Ullswater, they would then become four, and I should go on with four pipes.

1232. (*Sir J. Thwaites.*) What would be the character of the pipe which you would use?—Cast metal pipes, of seven feet diameter.

1233. Would you have them coated at all?—I should coat them with tar internally and externally.

1234. Of what use would the tar be internally?—To preserve the pipes. There are several compositions used for that purpose.

1235. (*Chairman.*) But what would you use?—There is a composition patented by Cochrane, but I should use a composition of gas tar. I would tar the pipes inside and out.

1236. (*Sir J. Thwaites.*) How long do you think the tar would last?—Of course, the waters rushing through from time to time would wash away the tar, but it would last a long time. I should say that it would last some two or three years.

1237. Have you had any experience with regard to that?—I have.

1238. What would be the advantage of having a coating of tar to last three years to pipes placed there for all time?—We put pipes down without any composition at all, but I should put some composition. I am not prepared to say just what, but the best composition I could obtain to preserve the pipes as long as possible.

1239. (*Chairman.*) When the composition wore out, what then?—The pipes must take their chance.

1240. Taking you from the lakes as you proceed onwards I see on the plan that there is a route which proposes the avoiding of a tunnel, is that to avoid this tunnel five and a half miles in length of which you have been speaking?—It should have been put "for the purpose of avoiding the tunnel at Shap Fell," the long tunnel.

1242. (*Sir J. Thwaites.*) You are not going through Shap Fell?—No, I am going round by Kirkby Stephen.

1243. (*Chairman.*) You have told us of a tunnel through limestone rock 5½ miles in length which would take from two to three years to construct; then I see at a place called King Meaburn you have a dotted line which says "route avoiding tunnel;" what tunnel is that?—Avoiding the tunnel through Orton Scar; the Ullswater and Haweswater one of 5½ miles in length.

1244. (*Sir J. Thwaites.*) Have you walked that ground?—No, I have looked it over on the Ordnance sheet.

1245. Do not you know that you would have about three tunnels there by the loop line, if we may so call it?—No; the levels on the Ordnance sheet show that I can bring it round by Kirkby Stephen into the valley at the head of the Lune. If a survey were made there might be a tunnel of some three-quarters of a mile in length, allowing for the gradients.

1246. But through Asby Scar, for example, you would have to tunnel through three times that length?—But that dotted line on the map is just put on approximately. In making a survey perhaps it would go a little nearer towards Appleby coming round by Kirkby Stephen.

1247. By the river Eden you mean?—Yes, nearer to the river Eden.

1248. (*Chairman.*) In fact the dotted line on this plan is not made accurately?—It is approximately accurate.

1249. But if you wished to avoid a tunnel you will have to go somewhere in the direction of Kirkby Stephen?—Yes.

1250. But you have not sufficiently surveyed that country for you to know whether that route would be possible?—I have not, but I am perfectly satisfied that it is possible from the levels on the Ordnance survey.

1251. (*Mr. Harrison.*) You say that you have calculated the size of your pipes according to the gradients, will you just refer to 56 miles on your section?—I may observe that the sizes of the pipes are not calculated according to the gradients on this section. The gradients are generally looked at and the sizes of the pipes determined, but this section was made as an approximate section to show in the first instance that the scheme was feasible as far as Leeds; and I put on these gradients, showing the surface of the ground and the proposed lines of pipes somewhere near the gradients. The sizes of the pipes are estimated approximately, allowing fully for the probable gradients to supply the whole of those towns.

1252. You commence at Ullswater by taking the water at a level of 467 feet, do you not?—Yes.

1253. At 56·67 miles the level of your pipes is shown as being 445 feet?—Yes.

1254. That gives a fall of 22 feet?—Yes.

1255. That gives for 56 miles $4\frac{3}{4}$ inches per mile as the average fall over that distance through your pipes?—Yes.

1256. That, of course, is the basis upon which your calculation will have to be made?—No, in this instance I shall have a greater fall than that. In the calculations which I have made the falls are not less than from 9 inches to a foot per mile; this $4\frac{1}{2}$ inches is only an approximation, and therefore not the fall on which I made my calculations.

1257. Then practically you cannot take this section as being of any use at at all for your purposes?—Not at all; it was merely put as an approximation.

1258. You could with that fall have made it an open conduit of sufficient magnitude to get it to one uniform centre, but surely not through pipes?—No.

1259. Have you at all in contemplation the supplying of any towns further to the eastward, for example York, which is badly supplied?—I have it in contemplation also, and Rotherham and Sheffield also. These waters being brought to Leeds could be trenched off, and the contour levels of the country would admit of these waters even being taken up to York and brought round by Rotherham to Doncaster, Sheffield, and all the towns in that district.

1260. But that is no part of your scheme?—No, my effort has been to attract the attention of the different towns to this source of supply only as a general scheme. I have not been able as a private individual to go further into it. I have spent a great deal of money, some 300*l.* or 400*l.*, in order to induce them to approach it, not as a matured scheme, but only as a feasible scheme.

1261. We may take your idea to be this, that it would be possible by gravitation to convey the waters from Ullswater and Haweswater into the valleys which run down to Leeds?—Yes, by gravitation to supply the different towns, and that it could be done at a reasonable cost.

1262. But you have hardly gone into that question sufficiently?—No. I submit this, that without a proper survey with sections and plans fully matured, no estimate can be made out except approximately for any scheme.

1263. What is the size of the tunnel that you calculate upon at Orton Scar?—For the four large pipes it should be 40 feet in width and 16 feet in height.

1264. (*Mr. Prestwich.*) How many miles of tunnel have you along the whole length of your line?—There are $5\frac{1}{2}$ miles at Orton Scar and some $2\frac{1}{2}$ miles near to Todmorden.

1265. Then you have under 10 miles of tunnel?—Those two would make eight miles.

1266. And what is the total length of the line?—170 miles.

1267. (*Mr. Harrison.*) Do you think that you could make a tunnel of that shape, 40 feet wide and 16 feet high all in one, or would you have to make two?—Yes, it would be better to have it made in two and to have a leg in the centre of the tunnel.

1268. What is your estimate per yard for the cost of that?—I have not the details with me to enable me to answer that question.

1269. (*Chairman.*) I observe that there are 20 towns to which you propose to bring water. In the return which you have given us you state that the highest level at Lancaster is 132 feet; that represents I presume the level which would be necessary to supply all the towns in Lancashire of that level by the Ordnance datum?—Yes, 132 feet is the highest level. Those level were furnished me by the Ordnance department, and I have found since that some portions of the towns are rather higher, and therefore this return would require some little alteration. In Lancashire I show that 20 towns can be supplied with water discharged into reservoirs by gravitation; then I show the highest level in the towns in feet above the Ordnance datum.

1270. You mean that the highest level in the town of Lancaster above Ordnance datum is 132 feet?—Yes.

1271. (*Sir J. Thwaites.*) Take the Castle Hill for example; surely that is more than 132 feet in height?—I wrote to Sir Henry James, and this is the return which I received from him of the highest levels of the towns, giving their bench marks, and I believe they are the highest levels of the towns excepting in one or two instances.

1272. The next column is headed "Head of water, Haweswater, 562 feet," what does that mean?—That is taking the natural level of the lake, say, at 694 feet above the Ordnance datum, there would be 562 feet head of water over the 132 feet, the highest level at Lancaster.

1273. Then "Head of water, Ullswater," you have put down as 345 feet; that is deducting 132 feet from 477 that would give 345 feet?—Yes.

1274. Will you have the goodness to put in that return?—(*The witness delivered in the same.*)

The following towns can be supplied with water discharged into reservoirs by gravitation, as shown by the following table:—

—	Highest Level, Feet.	Head of Water, Haweswater.	Head of Water, Ullswater.
Lancaster	132	562	345
Preston	140	554	337
Wigan	157	537	320
Dewsbury	187	507	290
Wakefield	201	493	276
Liverpool	227	467	250
Leeds	300	394	177
Bingley	278	416	199
Kendal	316	378	161
Bolton	327	367	150
Blackburn	373	321	104
Keighley	388	306	—
Bradford	420	274	—
Huddersfield	429	265	—
Burnley	492	232	—
Rochdale	472	222	—
Halifax	604	90	—
Manchester	—	—	—
Salford	—	—	—
Stockport	—	—	—

1275. (*Colonel Harness.*) When you speak of 150,000,000 gallons, what head are you using and what quantity of discharge?—In going into that matter and determining as to the size of the pipes, I have allowed over and above the size so as to be safe in the estimate, and the altitude of Haweswater being very much above that of Ullswater the velocity in those pipes would differ at different times; sometimes some of the lower towns, for instance Lancaster, would be supplied with water from Ullswater, and the higher levels of towns would be supplied from Haweswater, that being of higher altitude, so as to give a sufficient velocity to the head of water from the two lakes to pass through to the different towns at their various altitudes the quantities of water that they required to make up the 150,000,000 gallons which I have put down as their capacity.

1276. Have you calculated separately for each town what its proper head of water would be and then adopted the aggregate?—Yes, I have.

1277. (*Chairman.*) You have told us that you bring the water by means of two pipes from Haweswater and two pipes from Ullswater, that is four pipes, do you propose to continue to carry it by four pipes the whole way?—I propose to take four pipes to as far as Leeds, a distance of about 90 miles; then three pipes from Leeds to Bolton, a total distance from the lakes of about 145 miles; and from Bolton to Liverpool two lines of pipes, a distance of 170 miles.

1278. And that by iron pipes as you have described the whole way?—Yes, under various pressures, of which I can give some particulars if necessary.

T. Dale, Esq.

21 Feb. 1867.

1279. (*Sir John Thwaites.*) Do you mean various pressures upon the same pipe?—No; I can give the thickness of the rims, the pressure in feet, the weight per yard, and the cost per mile.

1280. (*Chairman.*) I see in one statement you have calculated that you would get a sufficient amount of capital for carrying out the works, will you give us what you consider to be the amount of the cost of the whole scheme?—I put the estimated cost of the works, *viâ* Leeds to Liverpool, including pipes, tunnel, trench works, town connexions, and all other materials and works required to be done, at 11,500,000*l.*, including the whole of this combined scheme. Then Parliamentary expenses and compensations, surveys, engineering, &c., 460,000*l.* in addition, making a total cost of 11,960,000*l.*, or say 12,000,000*l.* in round numbers.

1281. You propose by your statement in this paper to borrow that money by the aid of the Government at four per cent.; what do you mean by that? how are the Government to assist in it?—The Government are to lend the different corporations money at four per cent.

1282. (*Sir John Thwaites.*) How are the Government to raise that money?—I know that in carrying out sewerage works the various corporations have borrowed money from the Government, and money might be advanced in the same way for this purpose.

1283. (*Sir B. Phillips.*) Have they not rather borrowed them from public bodies under Acts of Parliament?—I think that that has been the way in which the money has been raised, and this is the idea that has occurred to me.

1284. (*Chairman.*) How long do you propose that those works should take in construction?—I should say that this combined scheme would take six years.

1285. (*Mr. Harrison.*) What have you added to the 12,000,000*l.* for the accruing interest during the construction of the works?—I have put nothing down for that; I have put down in the yearly expenditure interest at 4 per cent. upon that amount.

1286. What does that come to?—478,400*l.*

1287. Up to the time when you complete your works, the accruing interest during that period on your borrowed money would form a part of your capital?—It would.

1288. In addition, whatever it may be, to the 12,000,000*l.*?—It would.

1289. You would not borrow all the money at once, but if you take six years for construction, there would be the interest, say for three years, at 480,000*l.*, or in round numbers 1,500,000*l.* which would have to be added to this 12,000,000*l.* for accruing interest?—Yes, that would be so.

1290. That would make it 13,500,000*l.*?—Yes, that would be so, taking that view of it.

1291. (*Chairman.*) Have you made any calculation what the annual cost of keeping up those works would be?—Roughly I have done so. I provide also a sinking fund of 3 per cent. amounting to 358,800*l.*; that fund would be a sort of renewal of works fund, or to pay back the total amount of the cost of construction in a given number of years.

1292. (*Sir John Thwaites.*) What number of years do you calculate?—I calculate about 25 years at 3 per cent., but I have not worked that out.

1293. (*Chairman.*) The whole of this scheme is to be a supply by gravitation, is it not?—Yes, the towns are all to be supplied by gravitation.

1294. But in consequence of the immense expense which would fall upon any individual to make anything like an accurate survey of the country through which these works are to pass, your scheme deals rather in generalities and not much in details; it is more a general scheme which you have drawn up for the benefit of the corporations of those towns, in order to show them that instead of laying out their money in attempting to get water from the districts near to the towns which you have mentioned, it would be possible to bring water from Ullswater and Haweswater by means of iron pipes through the district which you have described, but that you are not prepared to go into any details of sections or levels as to how you would bring it?—I am not able to do so, because it is beyond my power and pecuniary means to do so.

1295. But the object that you have in view is to call the attention of the corporations of those different towns, to what in your opinion might be done for them to amend their present supply of water?—That has been my object.

1296. But yours is a very general scheme, and therefore must not be taken as anything like one that is perfect or fit to be criticized in detail?—Of course not; it is not a fully matured scheme, but this I have to say that I am fully convinced, so far as I have been able to go, that the works could be carried out for less money than I have put down.

1297. (*Mr. Prestwich.*) Many of those towns which you propose to supply with water are already supplied by collecting grounds on the millstone grit which you have told us is a good collecting ground; nevertheless, you consider it would be advantageous to substitute for such gathering grounds the gathering grounds of the lake district which you now suggest?—I do.

1298. Is there reason to believe that there is cause to object to the water supplied by those gathering grounds to those different towns?—I have received letters from some of them this morning, stating that the whole of the towns which I have mentioned are short in the quantity of water, that the waters are impure, and that when they have to apply to Parliament they meet with opposition from millowners and landowners, and that the sums of money that are spent are immense; and my object is, and what I wish to impress upon the Government is this, that they shall say to the people of the different towns the mountainous regions are the proper gathering grounds, and you shall have those gathering grounds; we will allow no more reservoirs to be constructed in valleys causing insecurity to property and deteriorating the value of the land that ought to be appropriated to manufacturing purposes and to agricultural purposes, but these are the gathering grounds that you shall go to and save all this amount of money. I also propose that there shall be an executive in London and a president of a water board appointed, who shall have control over the local directors the same as the general board in London has in the case of the poor law, and that those directors shall be representatives of various towns according to the rateable value of those towns, and that they shall sit at that board, but that their doings shall be under the control and sanction of the executive government. At the present time in obtaining quantities of water for towns the local representatives are generally men whose popularity rests upon their reducing the rates, and when they go for a scheme they go for the cheapest scheme that they possibly can without looking at the ultimate benefits to be derived from providing pure water for the population.

1299. (*Sir J. Thwaites.*) You are an officer of a municipality, are you not?—Yes, I am.

1300. Then you have not faith in municipal government?—I am speaking now with respect to what I consider false economy in providing water for various towns.

1301. Do not you think it right that municipalities shall spend as they please their own money?—Still there ought to be a controlling influence over them to see that their money is spent properly, especially where the health of the different populations is brought to bear, as is the case in Hull. I may say that we are cholera proof there; and I have some statistics, which I could produce if it were desired, as to the use of spring water and river water there.

1302. (*Mr. Harrison.*) Have you any special returns with regard to the Hull water?—In Hull we have had river water supplied to the town, and in the year 1849 there were some 2,000 deaths from cholera. Now, we have had spring water introduced from the chalk by an artesian well, which is yielding at the present time about 5,000,000 gallons of water per day, and during the last visitation of cholera last year we

had no cases, excepting about four which had been imported, and the people of Hull escaped.

1303. (*Chairman.*) I presume we may conclude that Hull is a great deal better drained now than it used to be?—It is undergoing drainage at the present time, and certainly that has to be considered as well, but bad water, I believe, is a great incentive to cholera.

1304. (*Mr. Harrison.*) If I recollect rightly, it was the sinking of a little well by the railway company to get water for their locomotive engines which induced the corporation to put down wells in the chalk?—The corporation of Hull have been for centuries in possession of natural springs at Springhead, near Hull, which formerly had supplied the town with water, but which had been disused, when the wants of a largely increased population required a much larger supply than they could yield. In consequence of which, about 25 years ago, recourse was had to the fresh water of the navigable river Hull; but this proving impure, about six years ago extensive works, with artesian bores of large diameter, were constructed on the site of the old wells at Springhead, at a great cost, from which a most abundant supply of pure spring water was had for the use of the town.

T. Dale, Esq.
21 Feb. 1867.

1305. The corporation charged so high for the very bad water which they supplied that the company put down a well in the chalk to supply water for their own engines?—Yes.

The witness withdrew.

Adjourned to Wednesday, the 6th of March, at 2 o'clock.

Wednesday, 6th March 1867.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND, K.G., IN THE CHAIR.

Sir JOHN THWAITES.	Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.	THOMAS ELLIOT HARRISON, Esq.

JOSEPH PRESTWICH, Esq.

ROBERT RAWLINSON, Esq., examined.

R. Rawlinson, Esq.
6 March 1867.

1306. (*Chairman.*) You are a Companion of the Bath, a Civil Engineer, and a Fellow of the Geological Society?—Yes.

1307. And you are officially engaged as principal inspector to the Local Government Act Office?—Yes.

1308. And you were government engineer to the Lancashire Board of Public Works in 1863 and 1864 during the cotton famine?—Yes, and I remain so; the works are not completed.

1309. And you are chairman of the Royal Commission which is now sitting to inquire into the pollution of rivers in England and Wales?—Yes.

1310. And a member of the Army Sanitary Commission at the War Office?—I am.

1311. You have been generally engaged in civil engineering since 1831?—Yes.

1312. Were you engaged on the London and Birmingham Railway?—Yes, I was for four years under the late Mr. Robert Stephenson.

1313. You were inspector under the First Board of Health?—Yes.

1314. Were you the Sanitary Commissioner sent out by the government to the army in the Crimea?—Yes.

1315. Where you were wounded, I believe?—Yes, I was.

1316. Have you generally given much attention to the subject of water supply?—Necessarily so. I have examined officially the reservoirs of Lancashire and Yorkshire for the Home Office since the bursting of the Dale Dyke Embankment, and have reported upon them.

1317. Have you also examined the Valley of the Thames?—Necessarily so, as chairman of the Rivers Pollution Commission I have, in conjunction with my brother commissioners, examined the main valley of the Thames and have reported to Parliament. The Thames Conservancy Act has been passed since, and is now in force.

1318. Did you report in the year 1846 on the proposed supply of water from Bala Lake, in North Wales, to Liverpool and other towns in Cheshire and Lancashire?—I did. I hold a copy of the report in my hand.

1319. Will you have the goodness to hand in that report?—Yes. (*The witness delivered in the same.*)

1320. Have you been engaged in the construction of impounding reservoirs?—I have. I am just completing an impounding reservoirs now for Swansea.

1321. And have you inspected impounding reservoirs in Lancashire, Yorkshire, Wales, and Ireland?—I have.

1322. Have you inspected the lake districts of Cumberland, parts of Scotland and parts of North Wales?—Yes.

1323. Have you carefully considered the natural features in mountainous districts, favourable and unfavourable for the formation of water works?—Yes, I have. There are many peculiar features in mountain districts which require an engineer to have some practical knowledge to know what form of bank should be put there, and what precautions should be taken to ensure its safety when there. I can quite imagine that natural features may present themselves which a person who had not had actual experience in reservoir making might think most desirable, but which if not duly considered might prove most disastrous if reservoirs are made.

1324. Have you also considered the geological characteristics of the several strata as favourable and also as unfavourable to the formation of impounding reservoirs?—Yes; the geology of a district requires to be very carefully considered and to be well understood in proposing to make large impounding reservoirs in fact artificial lakes; it would be a very risky thing to propose to make large impounding reservoirs, of very great capacity in the mountain limestone district for instance. There are many portions of the oolites where it would require very great care, and there are some geological characteristics which an unskilled engineer might imagine very favourable, but which, if he did not know what the ultimate consequences might be, would be very unfavourable. For instance, it might be considered a very favourable feature to have a valley where the subsoil was clay, and an engineer might think that he was very fortunate in having a clay subsoil upon which to form his embankment; but if he placed his embankment and his outlet works upon such clay subsoil without making proper arrangements for what might take place, that is to say, subsidence on compression, when he had nearly completed his work, he might find that he had spent his labour for

R. Rawlinson, Esq.

6 March 1867.

nothing. I have seen embankments made in such districts which have gone completely to ruin, and I have seen outlet works utterly destroyed. Again it is a very natural thing to imagine that clay would be about the best possible thing from which to make an embankment. Now the clays and marls of the oolites are most treacherous and about the worst possible thing an engineer could have to make embankments with. The clays of the lias will dig out apparently as sound as cheese, come out in big square lumps, but if put into an embankment and wet weather gets to them they will melt into the consistency of cream, and I have seen embankments where such clay has been used that would not lie at 7 to 1, they have melted like cream and run out at the foot and utterly ruined the work of the engineer. These are features which to experienced men of course are very well known, and to them I may seem to be talking nonsense; but to non-experienced men it is of the utmost importance that this knowledge of them should exist.

1325. (*Mr. Prestich.*) What is your reason for objecting to the mountain limestone or to the oolites?—First of all mountain limestone has been acted upon from the earliest time at which it has been exposed by the pure water raining down upon it and taking up the lime, that is to say, every million gallons of rain-water falling upon that limestone would take away about a ton of bicarbonate of lime, and carry it away, and it takes it away not uniformly over the whole area but from fissures. There are mountain limestones fissured from the surface to unknown depths in some instances. Take the case of Ireland, where there is an enormous amount of mountain limestone, and where lakes and large rivers lose themselves; there are lakes with no visible outlet but which have their outlet through the fissures of the limestone. For example, in the case of the two lakes at Galway, the upper lake empties itself into the lower lake in dry weather through the fissures; extreme floods do fill it up, and then the water goes over the surface. There are rivers in Galway which are swallowed up by swallow-holes: of course the water is not lost, it comes out again somewhere. Therefore if you attempted to make impounding reservoirs in mountain limestone you might have the surface space covered with vegetation hiding the fissures, so that an engineer might be at all the trouble of embanking a reservoir which would not hold water when it was made. The millstone grit is the same if injudiciously bared. In the case of one reservoir at Liverpool, known as the millstone embankment, the embankment was made from the inside of the reservoir; a large quarry was opened inside the reservoir space, but the water broke away through the fissures and got down through the sub-strata. I saw about a quarter of a mile below the embankment. I think it was something like 3,000,000 gallons of water had burst up in the middle of a field, and I understood that they had then spent 8,000*l.* or 10,000*l.* in trying to stop the leak, but never learned that they did stop it.

1326. (*Chairman.*) Have you considered at all the mode of supplying London from any of the high districts of the country?—I have not—that is to say, other than that I have read Mr. Bateman's pamphlet, and I have read the pamphlet of Mr. Hemans and Mr. Hassard, and I have read Mr. Dales's pamphlet, but before reading them I had not considered the question.

1327. Since reading them what conclusions have you arrived at as to the feasibility of bringing water from either district or both districts to London; in the first place, as to the feasibility of it setting aside the expense?—I have no doubt at all as to the feasibility. I think either Mr. Bateman's or Mr. Hassard's scheme could be carried out if expense is not a consideration, and most unquestionably I believe the volume of water which they propose to obtain and bring could be so obtained and brought, and of the quality which they indicate—that is to say, of a soft and pure quality. I do not know what Mr. Bateman wants with a conduit having 12 inches of fall to the mile, which I see he proposes to make. If he attempts to make a conduit having a surface grade of 12 inches to the mile, I am perfectly sure he cannot work it.

1328. (*Mr. Harrison.*) The average fall between where he proposes to take the water and London would be about 11 inches, but in the actual construction of his conduit I think the maximum which he allows at some particular places in tunnel is seven inches?—In tunnelling he may give what fall he likes, but in an open conduit of the magnitude which he contemplates I am perfectly certain he must give no such fall as 12 inches per mile.

1329. (*Sir J. Thwaites.*) You mean that it is too much?—Yes, the river Lee, with a very much less conduit than is proposed, has a fall of six inches per mile, but that is modified by stop gates and weirs. It is broken into vertical falls in fact. When you have a conduit above a certain size, when you begin to deal with water in millions of gallons, as in a canal (for it would be a huge canal, of course) an engineer would very soon find that he would get such a scouring velocity that he would have to modify it and put stop gates. I do not object to 12 inches. I believe that it would be a great advantage to have that amount of fall, but the water would have to go over vertical falls.

1330. The maximum fall which he proposes in any of his open conduits is six inches per mile?—Yes, and he would have to modify that by putting in stop gates. He could not run a conduit of that size with a surface grade of six inches per mile, it would cut his work to pieces.

1331. You are aware, are you not, that he proposes to line the whole of it from end to end?—If you get 2,000,000 or 3,000,000, or 5,000,000 or 6,000,000 gallons of water per day, you may have a conduit with a fall of five feet per mile, but as you get a larger volume you must lessen your grade. The Bridgewater canal has a velocity of $1\frac{1}{4}$ miles per hour, with only a surface fall given to it by drawing the locks at Runcorn.

1332. In that case they have merely the natural surface of the ground that it runs over?—Yes, the Bridgewater canal, which was laid out by Bentley, contours the country. Of course all canals are on the surface level, and any velocity that they have is the draught of the locks.

1333. The whole of it is not lined, I believe?—No, it is merely puddled—nor is the Lee.

1334. But Mr. Bateman, where he proposes to give six inches fall to the mile, proposes to line it entirely?—I am quite sure Mr. Bateman would have to put in stop gates. I do not say that that disparages his plan at all; I believe it would be better for it. I would rather have a vertical fall. I think it is a very providential thing that water will only work that way. I think it would aërate the water very much.

1335. (*Chairman.*) I gather from you that you think either scheme is quite feasible?—Most unquestionably, if money is not taken into consideration.

1336. I am speaking now, first of all as to the capability of the country, in either Wales or the Lakes district, to furnish the supply of water that is required?—I think that Mr. Bateman's area of country and the reservoirs which he has proposed would give the volumes which he has relied upon. He has had so very large an experience in collecting and storing and distributing water, that if I had no experience of my own, I should be inclined to rely upon his evidence; but I have had experience which corroborates his.

1337. You have not probably had any experience in that Welsh district as to the rainfall?—No; that is to say, I cannot give you actual gaugings, but still I believe that he is not far wrong there.

1338. How do you arrive at that conclusion?—In those mountainous countries, the countries on the west and south of England, of course the rainfall varies for every square mile, but I believe the average would be from 50 to 60 inches per annum; but then averages are not to be relied upon. You must not take averages,

you must take minimums, and that Mr. Bateman knows as well as I do.

1339. (*Mr. Harrison.*) I presume when you reported on Bala Lake you had your attention a good deal directed to the rainfall there?—Just so; and then I have returns every month from Swansea. I have a record of the daily rain gauge for the last six or seven years; the depth amounts to from 50 to 60 inches, and it is rather dry there. Mr. Bateman would have more rainfall than we should have at Swansea.

1340. (*Chairman.*) From your experience in that district you would have no doubt that Mr. Bateman's calculations are correct as to the quantity of water which he anticipates being able to obtain in that district?—I believe he would not have any difficulty. The questions as to storing it, and the advisability of storing by artificial means so large a volume, and the cost of storing it, are other questions, but his calculations as to the volume available I think may be relied upon, and as to the quality also.

1341. (*Mr. Harrison.*) Do you think that the 12 inches which Mr. Bateman calculates for waste would be sufficient for that particular district?—Yes, I think so.

1342. In fact, you have lately had your attention a great deal directed to the subject of what is available, as I judge from reading your report?—Yes, but your brother has gone far more fully into that question with regard to the Thames than I have, and I think he could give this commission some very interesting information. He has worked out from gaugings the actual rainfalls from the whole valley of the Thames, and he can give you more interesting information than any person I know, because he has thrown the information into diagrams.

1343. (*Chairman.*) I presume you have taken the quality of the water which he proposes to supply from Mr. Bateman's own statement?—Yes, and from my knowledge of the geology of the district. At Swansea the water is below four degrees of hardness, and that comes from sandstones in the coal stratification, in fact, it is part of the coal measures, and they are not calculated to give water so pure as the granites and clay slates, which Mr. Bateman's district is.

1344. What is the quality of the water in the lake district?—That is just the same—very soft.

1345. (*Sir B. Phillips.*) Have you turned your attention to the economy of using soft water as compared with hard?—Yes, necessarily. I was one of the inspectors under the Board of Health when their great report was written, and they had all the analysis before them, and I have fully considered the subject of economy in its use in every way.

1346. (*Chairman.*) Do you corroborate what Mr. Bateman states to the Commission that there is very great economy in household purposes and manufacture in the use of soft water over hard?—I have no hesitation in saying that Londoners could have tea of the same strength they are now drinking at half the expenditure of tea if they had water of the same quality as is supplied to Manchester as compared with the Thames water. They would save also in soap, and in the washing of linen, as also washing of clothes of all kinds, they would save directly in the less consumption of soap, and they would save indirectly in the less wear of the clothing, they would want less rubbing, they would save in labour in fact, and then for all steam purposes you get steam much better with soft water than you do with hard water. The amount of fuel is not perhaps an item which one would take much note of, but all users of steam power would pay more for soft water than they would for hard water, it does not foul the boilers. In the case of locomotives on the northern lines, as they go through Lancaster the Lancaster people supply them with water from the millstone grit, and there is something like 1,000*l.* a year paid in that little town by railway companies for supplying them with soft water, and it serves to cleanse the boilers or free them from sediment which they have got in the hard water district.

1347. The quality of the water being the same in the two cases, both the lake district and Wales, the result of course would be the same?—Yes.

1348. Mr. Bateman proposes to have large reservoirs but you seem to throw doubt upon the propriety of large reservoirs?—If the element of money is not to come into the field and consequently a few miles of distance would not be thought much of, I certainly should give the preference to that scheme which availed itself of natural lakes to the largest extent, and which did not require impounding rather than to one which trusted entirely for so large a daily volume of water to the system of artificial impounding.

1349. What is the objection that you would have to artificial impounding as proposed by Mr. Bateman?—There is always the risk that you have to contend against the elements, and if the works are not made with the most extreme care and much more costly, than any reservoirs which I have seen in my inspections, they will not stand. I believe that we have made mistakes in our modern engineering in reservoir embankment making, proprietors, companies, and local boards want the work to be done cheaply; but I hold that it is absolutely impossible to make a cheap embankment, that is, it is impossible to make a reservoir embankment at the same rate of cost at which railway embankments are made, and yet if you have to deal with local boards, they do not want to pay any more.

1350. Have you inspected the mode in which Mr. Bateman proposes to build these reservoirs?—That is a matter of detail to which he has given no key in his scheme, it is a matter for the future. I have seen some of Mr. Bateman's reservoirs in progress and some of the embankments which he is making—and I can only say in his presence that I should spend more money upon them than he is doing. If I were going to follow my profession as a reservoir maker, I should never sleep easy in my bed, if I did not watch most carefully every foot of the bank as it rose. Those reservoirs at Sheffield were very badly made.

1351. (*Sir B. Phillips.*) In other words you think that there is greater security in a natural than in an artificial reservoir?—Yes. The Hindoos have a forcible expression with regard to an arch, they say it never sleeps. That is absolutely true as regards water, for if you put water under pressure it never sleeps, it is everlastingly searching out the weakest point in the reservoir. For instance, look at the Dublin Reservoir, there never was a better bank put together. I saw it when they were making it, and I know that it was put most carefully together, but the water found out the weak point. I have not been there since the leakage has taken place, but I was there when the culvert was being made, and I remonstrated with the engineer. I begged of him not to make it of hewn ashlar, he thought that he was doing right, as I daresay nine out of 10 engineers would think, in making it of hewn granite ashlar; many engineers would infer that hewn granite ashlar was the best thing to use; but I am speaking in the presence of Mr. Harrison, who knows perhaps better than I do that in the case of ashlar of any kind if it has to resist water under pressure, the beds and joints are the weakest parts in the masonry, especially where there is the slightest liability to motion. I would either have made that outlet culvert of brick or rubble, I would have made that culvert of rubble if it had been my work, put together with one-third mortar. Mr. Hartley, the greatest dock engineer, I think all engineers will allow, as far as my reading goes, that any age has produced—certainly the greatest in modern times—began executing his docks of ashlar, hewn in such a manner as I believe stone was never hewn before since the world stood, so rigid and so careful was he. It would be too long a story to tell you how it was done, but that was the weakest work that he put together, and during the later years of his life for dock walls, and for river walls, and all the work he did, he used granite rubble. At the great granite quarries in Scotland from which the ashlar had been produced were mountains of what we term scablins, the pieces which are knocked off by the hammer and thrown to waste, those were brought up by ship

R. Rawlinson, Esq.

6 March 1867.

to Liverpool; and his dock walls, his river walls, his fence walls, and everything, were built of rubble. In fact he migrated from the fine hewn ashlar to rubble.

1352. (*Mr. Harrison.*) I do not understand that you at all assume that the banks proposed by Mr. Bateman could not be made in the particular cases he proposes?—No; I only assume that he must put more money in them than it has been customary to put into embankments previously, as far as I know of them, and very probably his great experience would lead him to do so.

1353. (*Chairman.*) What I gather from you is that you would have no objection whatever to a reservoir such as Mr. Bateman proposes, provided that it was properly made?—No; I think you may do as has been done in India, where there are embankments 3,000 years old, upon a scale larger than anything hat Mr. Bateman has projected, and with monsoon rains as heavy as anything we have here.

1354. (*Mr. Harrison.*) You are merely referring to these matters as showing that reservoirs require perhaps the most caution of any engineering works which are constructed in the present day?—Yes; as this evidence may be looked at hereafter, I am merely putting on record my expression of opinion that reservoir embankments cannot be made at the same rate of cost at which railway embankments are made; you cannot tip with waggons.

1355. These embankments which are proposed by Mr. Bateman, in point of fact would not be larger, would they, than some which have already been constructed in England?—No. The test of an embankment is its vertical depth, it is not its length, or anything of that kind, it is its vertical depth.

1356. We may take it, may we not, to be 80 feet depth?—There are plenty of reservoir embankments of that height, and I think that Mr. Bateman has made some himself 120 feet.

1357. I think that all engineers got a little warning from the failure of that Sheffield reservoir, and I think since that time we may assume that they will take a great deal of care in ascertaining by borings and otherwise the exact nature of the stratification before they commence to put a reservoir upon any particular place; and if all those precautions are taken, is there anything within your knowledge that would lead you to say that what Mr. Bateman proposes is a work beyond ordinary embankments for reservoirs which have been made in England?—No; I believe that those embankments which he proposes to make may be made, and that they would endure any amount of wear, and last as long as time itself.

1358. Your suggestion is that every one of those precautions should be taken primarily before the work is begun?—Yes. The Commissioners must not imagine that I am speaking thus in disparagement of Mr. Bateman's engineering skill. I am only putting on record my opinion as to how embankments have been made, and that some amendment is required for the future. When I use the word "amendment" I mean that an engineer must be backed up in incurring extra expenses; that he must not be ground down in his estimate. It is a most fatal thing to any company having to deal with embankment works, to want what they call a cheap job.

1359. As a result of your examination lately as chairman of the Rivers Pollution Commission, do you think that even the carrying out of the suggestions which you have made in your report on the Thames, will purify the water of the Thames so as to make it a desirable drinking water?—If you mean by that to ask me whether the Companies now pumping direct from the main Thames continuing to pump from the direct main Thames would get pure water I say No.

1360. Is it not quite clear that in order to avoid supplying impure water they must incur before long a considerable additional cost?—Necessarily in my opinion, I think that they could get water from the Thames for the London of the present, and for the London of the future, and that they might get it as pure as the stratification will admit of, but that it will never be such water as North Wales would give them, that is to say, it would always be water impregnated with lime to the extent of 14, 15, or 16 grains to the gallon which it is at present. If you took it from its spring sources, or if you took it from its gravelly subsoil on the margin of the main stream, you might get it without its mechanical impurities; but it would have its chemical impurity if you would call it impurity; you would still have the lime which is now in combination with the water.

1361. Had not Professor Way analyzed a great number of waters for your Commission during your sittings in various parts of the country?—Yes, he is analysing now all the waters from the Aire and Calder valley, and he is going out on Friday and Saturday to collect samples from the river Lee valley.

1362. I presume he will have formed a pretty good conclusion from all his experience as one of the members of your commission as to what is the best quality of water generally speaking for a large population?—He can inform this Commission as to the salts and mineral matters combined in waters. The economy and wholesomeness of water form parts of other questions.

1363. Is that a point which you have had to go into in your inquiries?—Not upon the Pollution of Rivers Commission. I had to go into it as an inspector of the first Board of Health when their first water report was published: it was then a duty imposed upon me to go into the question.

1364. And what was the result of your inquiries then?—The result was that we always recommended soft water to be sought for, and additional expense to be incurred to secure soft water in preference to hard water, for the purposes of domestic use, and as being more wholesome to drink.

1365. (*Mr. Prestwich.*) Have you paid attention to that particular subject as to which is the best water for health?—Excepting this that I find very curious and very conflicting evidence; but I believe it all wants qualification. You have populations living in soft water districts, and drinking soft water, and not only suffering no injury, but I believe gaining advantage by it; but if you removed a person from a hard water district to a soft water district, or *vicê versâ*, there is a great risk of your upsetting the economy of his system, and making him ill for a time. Sporting men understand it so thoroughly, that no man owning racehorses or training racehorses would dream of changing the water, whatever it be, that a horse has been trained upon, in the interval between the training and its race. If a groom gave a horse hard water that had been trained upon soft water, he would make it what a jockey or a groom knows as "penny;" his coat would stand up, and the horse would be out of condition. I believe that human beings are acted upon in the same way.

1366. (*Chairman.*) Must you not qualify that opinion, because it is not the practice, is it, to carry water about with horses?—Then I have been misinformed.

1367. For instance, if the horse is trained in Sussex and he runs at Doncaster, is water taken with him?—He has his water sent down in some cases. Of course your Grace knows a great deal better about these things than I do. I know that when the celebrated horse "Birmingham" won the St. Ledger he came from Birmingham, and (by repute) his water was sent up for him.

1368. Possibly that arises from the fear that somebody may what is called in the language of the turf "have got at his water" the place where he was going to?—That may be so, but I know that hard water will set a horse's coat wrong and make him what a groom would call penny. If you let him drink very hard water you would affect his skin directly. I know that soft water is preferred to train horses upon. The stables down in Yorkshire are upon the oolitic district, and there are some racing stables about Salisbury, and all the water is caught

on the slated roofs and taken down into cement tanks for the drinking of the horses.

1369. (*Mr. Prestwich.*) Is that on account of the water being so hard or on account of the deficiency of water?—No, it is on account of the softness of the rain water; there is never any deficiency of water in the oolites, you can get abundance of hard water.

1370. Do you know what the soil is in the neighbourhood of Salisbury?—They have plenty of chalk water there, but they catch the roof water for the horses. I think there are some training stables near St. Giles's and they catch their roof water there and take it into tanks. When I wrote the report which I have handed in I read up the literature of water to a very great extent, both what prose writers have said, and what poets have said about it, and there is this fact with regard to hard and soft water. All soft water districts have a race of people much healthier, better looking, with fresher complexions than the people living in the hard water districts. It is very curious that all the crêtenism and goitres of the mountain districts are located upon the limestone in the Alpine district; the Alps are oolitic generally.

1371. Do you say that the people are more healthy in soft water districts?—Yes, they have fresh complexions, and that has been remarked in all ages and by all writers. The old poets of the East sing of the sweet waters and the Circassian poets also. The Circassian valleys from the clay slates and granites produce soft water. In all the fresh water districts, the Bala district and the valley of the Dee, the girls are noted for the freshness of their complexion and their personal beauty.

1372. What is the quality of the water in the Highlands of Scotland?—It is soft. It is from the granites and clay slates. And with regard to the unwholesomeness or risk of changing from hard water to soft or changing the water generally when the Duke of Cumberland went into the Highlands after 1745 his entire army was disorganized by drinking the lake waters which brought on diarrhœa and spasms. Sir John Pringle records these facts in his journal, and I can quite understand it. I have been twice in the Highlands of Scotland and having read up this question of soft water, and being so thoroughly imbued with the idea that soft water must be beneficial, I took to drinking a tumbler before breakfast and it brought on spasms. I did that twice with the same result, and I have no doubt at all that the soft water possessing more of the property of a solvent, acted upon the gastric juices and put me in a condition which I found very undesirable.

1373. Do you think the water which is used in Scotland is very wholesome water?—It is wholesome for the people who live in Scotland, but as I say before one was acclamatized to it it would be risky for any person to drink the water without proper precaution. That question of water drinking is not sufficiently paid attention to by our physicians. There is not a favourite sea bathing or summer place on the coast of England on the east or the south which does not give you very hard water, and if very delicate people are sent down to Scarborough the water is hard. It is hard at Brighton, and it is hard at all those places on that coast.

1374. (*Mr. Harrison.*) Taking it as a whole after they get acclimatized to soft water, if we may use the expression, the result of your information and experience is that the soft water is decidedly the best?—I think so; all the evidence is in that direction. For instance, it seems to be more wholesome, at least I am told that persons who pay attention to the breeding of stock and especially of horses prefer soft water. I think that all animals themselves prefer soft water to drink. You will find that horses and cows will go to a dirty ditch rather than go to a bright spring.

1375. (*Sir B. Phillips.*) According to your theory, having lived in London, you think that people having been accustomed to hard water if you were to bring in a supply of pure soft water, would for a considerable time until they became used to it necessarily suffer in health?—In the masses of the people you would have a per-centage that it would effect, but we unfortunately do not drink so much water as we ought, any of us.

1376. (*Mr. Harrison.*) Out of 30 gallons, taking it at 30, which is supposed to be consumed per head in London, what proportion do you suppose is actually used for drinking?—I should think that if you take London all over you would not have one half a pint per day of water drunk per head. I profess to be a water drinker simply because nature will not let me drink anything else, but then I am also a tea drinker: I do not perhaps drink half a tumbler of water in a day, and yet I cannot drink beer.

1377. (*Mr. Prestwich.*) I suppose that nineteen-twentieths of the water used for drinking in England is hard water?—I think it would be so, that is if you take nine or ten degrees as hard water, and we say that all above six degrees would come into the list of hard waters, and that all below six degrees you would call soft waters—that is six grains of lime, or bi-carbonate of lime, to the gallon.

1378. May not the observation which you made just now with regard to the better health of people in districts where soft water is used arise from the circumstance that almost always when you get into a mountainous district, you get into a granite or a slate district where the water is necessarily soft, and also as we know that in mountainous districts the air is generally pure, may not the better health arise from the purity of the air as well as from the softness of the water?—Yes, that may be so where the water is soft and pure, but you have a most degraded type of human life in mountainous districts also. I do not know that you can show in soft water districts anything analogous to the crêtinism and idiotcy which are to be met with in the hard-water valleys and mountain ranges of Switzerland.

1379. Has that not also been ascribed to the confined air of the valleys and other causes?—I think it is the result of a combination of causes. I think it may be due to the miserable and wretched way in which they house themselves, and very probably to the bad and innutritious food which they are brought up upon owing to the poverty which exists there, but as far as I am aware you never find the same amount of disease in a pure water district.

1380. But the water in the valleys where crêtinism prevails differs so very greatly—in some places the water is soft and in other cases it is hard—and I believe that the theory which ascribes crêtinism to the quality of the water has been given up because in many cases the water used is merely melted snow water?—That possibly may be the case.

1381. (*Sir J. Thwaites.*) You have prepared a plan for supplying Liverpool with water, have you not?—Yes; the plan which is described in the report which I have handed in, and which was prepared 20 years ago, in 1846, was to take in water from the valley of the Dee, which has Bala Lake at its head, and that is essentially soft water.

1382. Have your views altered at all as to the capacity of that lake to supply Liverpool?—No; if you look at this report you will see that I proposed to make a conduit commencing 30 or 40 miles below the lake, and to have made the lake into an impounding reservoir on a plan similar to that which Mr. Bateman has adopted in his great Glasgow works.

1383. That part coloured blue in your map, which is gathering ground, comprises an area of 289 square miles?—Yes.

1384. And that coloured dark blue an area of 38 square miles?—Yes.

1385. Do you propose to utilize this lake as a reservoir?—I did; I suggested that.

1386. Has subsequent reflection caused you to alter your previous view?—No. I do not know what has been done on the margin of the lake; I have seen a map with a railway carried alongside of it, but there was no such railway when I was there 20 years ago.

R. Rawlinson, Esq.

6 March 1867.

1387. That would prevent, would it not, your raising the level of the surface of the lake?—No, because I should propose to shift the railway higher up.

1388. Did you propose to raise the surface level?—Yes; I proposed to raise it 6 feet, and drive a heading and draw off 12 feet, and I should take power to draw it 12 feet below the ordinary level and to raise it 6 feet above.

1389. Are there any houses surrounding this lake?—There were not at that time.

1390. What is the utmost quantity of water that you hoped to obtain from this source?—I proposed in 1846, I think, to have given them works for 30,000,000 gallons, but all the permanent portion was capable of going up to 60,000,000 gallons per day.

1391. Is that the maximum?—No; the volume of water passing through the bridge at Llangollen is at least 550,000,000 gallons per day; the average quantity, taking 365 days, the minimum dry weather flow is about 60,000,000 gallons.

1392. You separate the 38 square miles, do you regard that as auxiliary?—Yes; there is a mountain ridge, what is called the Berwyn mountains, 2,000 feet high, between the two areas.

1393. Can you tell us the amount of rainfall on this district, the area of which is 289 square miles?—It varies from about 40 to 80 inches per annum.

1394. What is the average?—About 60.

1395. What deduction from the average of 60 inches have you made for absorption and evaporation?—The area is so enormous and so much beyond what the requirements of all Lancashire could be that I never troubled myself about that.

1396. Did you gauge the water near to the bridge at Llangollen?—There is a weir to supply the Ellesmere canal at a place called Llantysilio, about three miles above Llangollen, and I gauged it there several times. There is a conduit which carries the water across the Pont-y-cysslte aqueduct, taking 20,000,000 gallons per day for the supply of the Ellesmere canal; I gauged it frequently at that weir, which was made by Mr. Telford.

1397. (*Col. Harness.*) Then the quantity passing under Llangollen Bridge is what flows down after that is taken away?—Yes; they take 20,000,000 gallons regularly for the supply of the canal.

1398. (*Sir J. Thwaites.*) What quantity in the average of an ordinary year's rainfall passes under that bridge after the abstraction of 20,000,000 gallons?—About 550,000,000 gallons per day in round numbers.

1399. Do you state in your pamphlet what height this is above the ordnance datum?—It is 330 and some odd feet at the point Llantysilio.

1400. The lake is higher than that, is it not?—Yes, it is higher, but I do not exactly know how much; it would be upwards of 400 feet.

1401. What is the distance from the lake to Liverpool by the line you take?—I intended to take my supply at Llantysilio, which is 64 miles from Liverpool by a line of conduit.

1402. What fall did you give to your conduit?—I think 10 inches per mile.

1403. What would be the size of your conduit?—I do not remember now; I think it was about 10 feet wide; I intended to make it to take 60,000,000 gallons per day.

1404. You objected, did you not, to Mr. Bateman's conduit giving a fall of 12 inches per mile because it would tear up the whole thing?—It is no objection; I only say he could not work a conduit with that fall, he would have to put in arrangements to stop the velocity.

1405. Did you propose to put in those weirs?—I should have been obliged to do it, nature would have made me do it; I should very soon have found that out, but I was not as wise then as I am now.

1406. As far as you are able to judge, the capacity of this area of 289 square miles, and especially if the 38 square miles were added to it, would be equal to supply with water several large towns in Lancashire?—It would supply all the county.

1407. Do you think that the water of this district would be sufficient for the supply of the metropolis?—Yes; Mr. Bateman has thought all about it, but he has taken his other source because of the engineering difficulty about getting it there.

1408. Taking 4,000,000 as the mean population and allowing 30 or 40 gallons per head, what is your view as to the quantity of water per head, with regard to sanitary, manufacturing, and other objects?—You have about 100,000,000 or 108,000,000 gallons of water flowing into London per day now. My own impression is that more than a moiety of that water is wasted—is not used for any useful purpose.

1409. What do you consider to be a sufficient maximum quantity of water per head *per diem*?—There are 36 gallons per head now, and if the companies by bad arrangements of distribution waste half of it, that gives a volume that is used of about 16 or 17 gallons per head per day.

1410. I assume that if your plan were ultimately carried out for supplying the town of Liverpool with water, it would be a plan carefully considered and well calculated in all its details, and that there should be no waste in distribution?—That I would not undertake to guarantee. Waste must be checked by constant supervision after the works have been completed.

1411. Allowing a margin for waste, what quantity would you say was sufficient per head?—I should say 30 gallons per head.

1412. Taking the population at 4,000,000, is it your opinion, having regard to the area which you have coloured on this map dark and light blue, that that area would be equal to the supply of the metropolis with water?—That makes 120,000,000 gallons, and I say that you have with 48 inches of rain per annum flowing from the 289 square miles, about 550,000,000 gallons, passing under Llangollen bridge, so that you have nearly five times that.

1413. But of course you must leave a sufficient quantity of water to have some compensating powers so as not to destroy those rivers?—Yes; but you have a volume five times larger than the 120,000,000, and with a similar rainfall 48 in the 38 square miles will give about 72¼ millions of gallons per day additional.

1414. Then I understand generally there would be no doubt in your opinion that this area will yield a sufficient supply of water for the whole of the metropolis?—Yes, no doubt.

1415. (*Mr. Harrison.*) The level from which you would take the water being, as you say, 330 feet would not enable you to take it to London to give a high level supply?—No; besides there are intervening mountains between that district and London which would almost render it impracticable. There are the Berwyn mountains, that range right down between the Severn valley and the Dee valley.

1416. (*Sir J. Thwaites.*) Could you not take it to Stoke, as Mr. Hassard proposes, and there form a junction with his main culvert?—I have never thought that out, I have never paid attention to taking it to London.

1417. What is the level of Bala lake?—I do not remember, I know I put it down higher than it is.

1418. It is 530 feet?—Then you have 200 feet rise above Llangollen.

1419. If Mr. Hassard can bring it from Bala lake to London in connexion with his own tunnel, it is practicable for any one else to bring it and have an independent supply?—Yes, certainly. If it were a question of supplying London from this district, you can get it at the elevation which Mr. Hassard states it at, 450 feet, or whatever it may be.

1420. You mean taking the area which drains into the lake?—Yes, and a portion of the river a mile or two below it, and all its tributaries, and there are magnificient sites for reservoirs there, if reservoirs were required.

1421. (*Mr. Harrison.*) That would be an area in acreage of fully half what you put down there, but

yielding much more water per acre, a great deal of it being higher up the hills?—It does not follow as a matter of course, that you get more water because you rise.

1422. That I understand, but would not that particular district produce more water?—I think it would, because it has the first catch of the rain-clouds that come over from the Atlantic.

1423. (*Chairman.*) Are we to understand you that this scheme is now being taken up by the authorities of Liverpool?—No; it is simply that Mr. Duncan, the waterworks engineer, in consequence of the failure for the last two years of the works which they have carried out, at Rivington, the storage reservoirs falling much shorter than they had anticipated, and Liverpool and its suburbs having grown more rapidly than they anticipated, was called upon by the corporation to report as to the best district to supplement the supply, and in his conclusions he says that the advantages are in favour of Bala; beyond that they have not gone excepting by a resolution of the town council to request the engineer to see what additions can be made to their present means of supply, and to see if they cannot make them meet the wants of the time. They have not taken it upfurther than that, and Mr. Duncan simply gives an expression of opinion that it would be best to go to Bala if a change is made.

1424. (*Mr. Harrison.*) Supposing that water from either of the Cumberland lakes or from Bala lake, or from the Welsh mountains, of the softness of which it is stated to be, could be commercially brought to London, from your large sanitary experience do you consider that it would be a great object for the citizens of London to bring such pure and soft water to them?—I do; and I would go further than that and say that any person who has had the luxury of living and washing and using water in a soft water district, I think would willingly pay double his water rates if he was capable of paying them. I am speaking of persons who have the means of paying; I would willingly do so. Say that my water rates are now 6*l.* or 7*l.* a year, I would willingly pay 14*l.* a year if I could have the Manchester water to wash in for my ablutions, for its comfort and economy and pleasantness. I cannot describe the difference. Your skin feels more wholesome and comfortable, and you wash your hands with much more pleasure, and especially in the spring time of the year. You have not that wretched chapping which many persons suffer from. If you bring soft water for the first time into a place where people have been accustomed to use soap, ignorant people will complain about this water for a time that they cannot wash the soap off; instead of letting the soap alone they go and lather it on as they had been accustomed to before, and then they cannot get rid of it.

R. Rawlinson, Esq.
6 March 1867.

1425. (*Chairman.*) Have you any further information to give to the Commission which you think would assist them in their inquiry?—With regard to rainfall, I may say that I have examined the records of rainfall from all parts of the world where I could get access to them, and I have come to this general conclusion, although, of course, everything that is generalized must be taken with its grain of salt, that the seasons in any country will vary about as one to two. Take London, for instance, if your driest year is 16 inches your wettest year will run up to 32 inches, and then your medium will be 24. In Mr. Beardmore's book, where he gives the rainfalls of North America, India, Australia, the Austrian Empire, and many other places, I could point out dozens of instances where it is true. Ten or 15 years are not sufficient to test excesses of rainfall. Take it in round terms the seasons give about as one to two.

The witness withdrew.

Adjourned to to-morrow at 11 o'clock.

Thursday, 7th March 1867.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND, K.G., IN THE CHAIR.

Sir JOHN THWAITES.	Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.	THOMAS ELLIOT HARRISON, Esq.

J. PRESTWICH, Esq.

ROBERT RAWLINSON, Esq., further examined.

R. Rawlinson, Esq.
7 March 1867.

1426. (*Chairman.*) Do you wish to offer any observations to the Commission in addition to your evidence of yesterday?—Yes; if the Commissioners will allow me, I will name a matter which has occurred to myself in reporting upon water supplies, namely, that in my opinion it would be advisable if engineers and others could come to some definite understanding with regard to a waterworks nomenclature. I see in the reports and documents words are used as synonyms which I think ought not to be so used. You will find that in these reports the word "quantity" is used with regard to water in volume, and the word "run" is used for water in motion. I cannot help thinking, though none of our dictionaries give us satisfactory definitions on this point, that it would lead to a clearness of conception if we used the word "volume" for water in bulk, and if we use the word "flow" for water in motion. I cannot conceive that it is proper to speak of water descending a conduit as running, because if we consider our language, we run with our legs, and running ought to imply a special kind of motion. I think the word "flowing" cannot be misunderstood. We say that water flows from a pipe, it flows down a conduit, and it flows down a river. But our language is rather loose in this respect. Every engineer and every literary man uses his own judgment, but in a report it would be well if words were used consistently. Occasionally the word "volume" is used, and then the word "quantity" for the same thing—water in *bulk* or *volume*. We say a quantity of potatoes, a quantity of coals, or a quantity of apples, but hardly with propriety, the quantity of water that is in the ocean. Perhaps the Commissioners will excuse my having mentioned this. In the report of the Commission of which I am a member, we adopted the rule to use "*volume*" and "*flow*" for water in *bulk* and in *motion*. I think the report reads more consistently.

1427. Have you any evidence to give the Commission upon the subject of the rainfall?—There are some general remarks that I was anxious to lay before the Commission. As the report of the Commission will be looked to with very great interest, and therefore a few broad general facts may be embodied in it which, although old news to adepts, may be of general interest, and the facts might not be noticed in the same way in which I shall put them. With regard to rainfall, I stated yesterday the broad general fact that rain varies, in seasons, about as one to two; and I said that after having examined the records of rainfalls from all parts of the world where they have been kept for any length of time, that I am borne out by the facts recorded. Engineers and others have got into the way of talking of averages, but averages of anything are liable to be very misleading, especially in meteorology. Liverpool,

R. Rawlinson, Esq.

7 March 1867.

for instance, was led to rely upon an average of rainfalls, but two or three consecutive dry years proved that it is the minimum which measures the capacity of the works, and not the average, because in such a case you are brought down to the minimum; the Liverpool people were told that they might rely upon 18,000,000 gallons per day after paying compensation. I think they were reduced for two years previous to this year, as low as from 6,000,000 to 8,000,000 gallons per day. Now that landed them in a very great scarcity; their reservoirs were nearly run empty, and if the drought had continued a very short time longer, they would have been under very heavy charges for compensation; they would not have been enabled to pay their compensations in water. If you take the fact that the years vary, as I state they do, from one to two, then if you have a minimum rainfall of 20, your maximum will be 40, and of course your average will be 30. If the average of years is given to you, and you want to know either the maximum or the minimum, by taking one-third and deducting it from the average that will give you the minimum, and adding it to the average will give you the maximum, as you will see very easily.

1428. (*Sir J. Thwaites.*) Is that borne out by Mr. Beardmore's tables?—I am giving you now what is not mathematically correct, and Mr. Beardmore says nothing about it; I am only telling how, if you have the average given, you may get approximately at the minimum or at the maximum.

1429. (*Mr. Prestwich.*) But you must know the maximum and the minimum before you get the average?—You may have the rainfall for 20 years; of course rainfall varies, it is 25 inches this year, 27 inches next year, 23 inches the year after, and then you strike an average; but you may have neither the maximum nor the minimum in any of those years.

1430. It is only from a known maximum and minimum that you can calculate the average?—Just so; but to get the maximum or the minimum the gaugings may perhaps range over a period of 50 years, but you do not always get it with a range of 10 years.

1431. (*Sir J. Thwaites.*) If you take your average for a period of 10 years, would you not consider that a fair average of rainfall?—No, certainly not.

1432. Is it your principle that in determining the quantity of water due to a given area you should fix upon the very smallest amount of rainfall in any part of the year or any part of a number of years?—You should fix upon the smallest annual volume of rainfall. Take for instance this great scheme; supposing you were going to tie London up to North Wales, and that you were going to rely upon storage, and that you were relying upon an average of any number of years. You have paid no attention to the minimum; you will find that you should have deducted one-third from that average.

1433. Pardon me, you have paid attention to the minimum, because that is an element in drawing your average?—Yes, but you have rejected that by taking and relying upon the average. I am supposing that you are relying upon the average.

1434. But all plus the average you know will bring up the minimum; what was the object of taking an average if it is not to produce that result?—But still do you not see that if you make works capable of storing and giving out the average rainfall, and if you proportion out your supply to the average rainfall as the Liverpool people did, when you come to have one, two, and three years of a minimum your average has simply been a delusion to you.

1435. Is not taking the average the first step to determine the quantity of water that you may reasonably expect from a given area?—No.

1436. Would not the next prudent step be to allow yourself a margin calculating the amount of water which you would probably require?—If you will do as I say, if you will deduct one-third from the average, whatever it may be, then you will make the margin which I say you ought to make, then you will have your minimum. If you take, for instance, the rainfall of a dry year at 30 inches, and if you take a wet year at 60 inches, that gives you 90, and half of it is 45. If you are relying upon 45 inches, because you have that average over a number of years, I say you must take 45 minus 15 which will give you 30, and then you must take your 45 if you want the maximum plus 15 which will give you 60.

1437. (*Chairman.*) You mean in taking those figures for example that the utmost outside quantity of water that you could calculate upon would be 60 inches, and that you could also make yourself quite certain that you would not be below 30?—The volume that you would have to fear for mischief would be 60, and the volume that you would have to fear for scarcity would be 30, or thereabouts; using these figures to indicate the probable, in special years there may be a few inches above or below the even numbers given.

1438. (*Sir J. Thwaites.*) Are we to understand that the object of the remarks which you have made with regard to the average of rainfall is to guard against the supposition that any scheme which professes to supply the inhabitants of any given town with water should not be calculated upon the average but that there must be a deduction, and of, in your judgment, one-third from that average as a proper deduction to make that quantity safe?—I think so, the same as I say is exemplified in Liverpool; they have been landed in a very grievous mistake because they relied upon the supposed average.

1439. (*Sir B. Phillips.*) What average did they rely upon?—I really forget; it is recorded in the papers, but their works were calculated upon an average and they have not realized it. They were told that they were to have 18,000,000 gallons a day, and that they were to do away with all their pumping stations, and to save about 25,000*l.* a year; they have never been enabled to do away with pumping, but have been obliged to increase it and to have a considerably larger amount of storage than was at first proposed.

1440. (*Col. Harness.*) Do you know how many days storage they have at Liverpool?—No, I do not remember; I think it is about 120. There is another fact with regard to meteorology which is not always attended to, which is sometimes forgotten, namely, the fact of excessive rainfalls, and the danger of excessive rainfalls. Great destruction occurs in this country at intervals by excesses of rainfalls. There is a prevailing notion all over the country that something or other has occurred to alter the seasons in this climate. It was quite curious that when the Rivers Pollution Commissioners were holding their inquiry in Yorkshire, during our first sittings we had evidence from all sorts of people to that effect, that land drainage, making storage reservoirs, and general cultivation had so altered the character of the country and the climate, that there had been no floods anything like the floods which occurred formerly, and the witnesses did not expect that there would ever be such floods again. Before we concluded our course of inquiries in Yorkshire, while we were sitting at Halifax that great storm occurred which is said to have done damage to the extent of from half a million to a million sterling in the valley of the Aire and Calder alo ne,showing how falsely the reasoning had been that nature had changed its character in consequence of the little puny efforts which men have made upon the surface, and I think that fact should be strongly impressed upon engineers and others who have to contend with the elements. We may rely upon it there is nothing that we can do upon the surface of this globe which will have anything but an infinitesimal effect in altering meteorology; it is independent altogether of our efforts. We may alter it in its small falls, but certainly we do not touch it in its excesses. That flood which occurred in Yorkshire last autumn was as destructive (in fact more destructive, because there was more property to destroy) as any we have any record of; it did incalculable damage, and it has done damage which might have been prevented if a proper and wise forethought had been taken

and proper arrangements had been made to guard against such excesses. If people had not blindly brought their property into danger, and gone on as they were going on, a good deal of the damage might have been prevented. Leeds, in some low parts, was six feet under water, and they were carrying provisions, lights, and fire about in boats to the poor wretched inhabitants who were confined in their houses. We had evidence from manufacturers, that in some of the valleys within the last 20 years they had lost more by floods than the whole worth of their property. In Todmorden, right up in the hills, we went through some large weaving sheds and workshops where looms, carding machines, and other engines, worth hundreds of pounds, had been destroyed; the water had been four feet high in the workshops. All that could have been guarded against by proper works and proper regulations. Bridges are washed down, culverts are blown up, and all this mischief is done because people choose to forget that nature now and then runs into those excesses, that she has done so before, and that she will inevitably do so again.

1441. (*Chairman.*) Does that apply as an objection to any particular mode of storing the water?—I should say that where you contemplate making such lakes as Mr. Bateman speaks of upon the upper Severn, if they are not made with a full knowledge of what nature will do in her wildest excesses, it is quite possible that those banks will be swept away like leathers. In North Wales during the time I was making an examination for my Bala lake scheme a storm occurred one night upon the Berwyn mountains in 1846, and the effects are seen at this moment. The rain began in the evening, it continued all through the night, and it brought down thousands of tons of stones and gravel; it left the old watercourses and it broke out new ones; it swept the débris down from those Berwyn mountains; and it levelled the village of Corwen up to the eaves of the houses, the church and all, and so they remain to this day; they were obliged to be cleared out and they are like cellar dwellings. The flood brought down thousands of tons of solid matter in that single night, and it carried bridges away which had stood beyond the memory of the oldest man.

1442. (*Sir B. Phillips.*) I thought I understood you to say that these reservoirs might be built imperishably, so that they may stand for all time?—Then they must be built very differently from anything that I have seen in modern times.

1443. I am speaking of the fact as to whether they can or cannot be so constructed as to defy the destructive element of which you speak?—I believe that they can.

1444. Then your observation is merely directed to this fact, that if they are not built of sufficient strength to resist what you call the volume of water at certain seasons they may be very dangerous, in other words that they would give way altogether?—Just so. For instance, those rains last autumn swept a large stone viaduct down in Yorkshire, which I say is a disgrace to the engineering science that put it up. There is a wide valley there, and a magnificent looking stone reservoir was swept helplessly down in one night.

1445. (*Sir J. Thwaites.*) Supposing that the dams are made with proper care and proper material, of sufficient strength, and with all the proper sluice arrangements and storm outflows so that the pressure would not be increased upon such dams; is there much fear that those dams will be carried down by such storms?—Not if those wild excesses of nature are contemplated beforehand and provided against.

1446. You would not have more hydraulic pressure if your reservoir is filled and if you have sufficient means of escape to meet those wild excesses to which you refer, then the dam would not be injured?—No, it might not; but as I say the dam must be built upon very different principles from those which I have seen.

1447. But you would always assume that any engineer of intelligence having regard to the experience of the part would build his dam with care and with proper materials?—I do not assume anything of the kind; I am afraid I must assume the contrary. I feel bound to speak to you as strongly as I can use language. I do not assume anything of the kind, I wish I could.

1448. (*Chairman.*) You have given the Commissioners, have you not, the period during which you would be satisfied with gaugings being taken to give an average of the rainfall in any particular district?—You cannot get the excesses, the maximum, and minimum that a country will give; if you do it is quite accidental, under 40 or 50 years, you certainly cannot rely upon any gaugings for 10 years.

1449. You would not be prepared to say that no scheme should be sanctioned till the rainfall has been taken for 20 or 30 years?—No, unless an engineer was determined to push a scheme forward on which he was taking the margin given him by four or five years rainfall; I should recommend him certainly to make a very considerable deduction and to take off at least one-third of his average for that period.

1450. Are we to understand you to say that one-third taken off and one-third added would be equivalent in your estimation to the experience of 20 or 25 years?—No; there must be a liberal deduction to make any engineer safe.

1451. (*Sir J. Thwaites.*) In the case of your scheme conceived 20 years ago with reference to the supply of Liverpool from Bala lake, was that subject to a deduction of one-third, or was the margin so great that your attention was not directed to that point?—The margin was so great and the area was so much in excess of what was required, that it was not necessary for me to do so.

1452. (*Chairman.*) Have you any other point which you wish to put before the Commission?—With regard to maximums and minimums of flow, Mr. Bateman's evidence agrees with my experience and evidence. In this country and in this climate (surfaces of chalk, oolite, and some others excepted) the dry weather flow is to the wet weather flow as 1 to 300 in ordinary periods, and as 1 to 500 and 600 in excesses. Mr. Bateman names 1 in 1,000, and I have no doubt that he is correct for limited areas. If you have an ordinary stream in dry weather, giving you any volume of water, the flood in that stream will be 300 or 400 times that volume, and it may rise for a short time up to 600 or 700, and even to 1,000. I do not mean for 24 hours, because the mischief is done in seconds. Then, although in this climate you have nothing like the tropical monsoon rainfalls for continuance, and the rainfall in this climate varies from the wettest part in Cumberland of 150 inches to the dryest on the eastern coast of about 17 inches, yet you may have as violent an excess on the east coast of England, with its 17 inches of rainfall, and as much mischief, if sufficient precautions have not been taken, as you will have in the wettest district with its 150 inches, or amidst monsoon rains, because thunderstorms, which are common, and occur all over the country, are as capable of pouring down as violent an outpour of water in this climate as a thunderstorm can pour out in the tropics. We have had instances in London in which two inches of rain have fallen in about half an hour, four inches in the hour—there you have the element of destruction in its concentrated form. I very much question whether, taking time into account, you could get a heavier rainfall in any part of the world.

The witness withdrew.

Professor J. T. Way.

7 March 1867.

Professor JOHN THOMAS WAY examined.

1453. (*Chairman.*) You are a professor of chemistry I believe?—Yes. I am not attached to any college at present. I am an analytical chemist, and I am a member of the Rivers Commission.

1454. Have you made any analysis of any of the waters in the lake district or in the Welsh district?—I examined some waters for Mr. Hemans' and Mr. Hassard's plan, which analysis I have given in this pamphlet of Mr. Hemans, at page 13, and I think the Commission have had it in evidence. There are four samples of the water; from the river Lowther, from Haweswater lake, from Ullswater lake, and from Thirlmere.

1455. What is the character of the water taken from those places?—The waters of the three lakes have a character very much alike; they are soft, bright, good waters. The river Lowther differs a little, but still it is a fairly good water; not so good as the others, but a very fair water.

1456. What is the number of degrees at which you would fix water as being soft or hard?—The water which we use in London from the companies is 13 or 14 degrees of hardness on the average; that, in Yorkshire, would be called very hard water, for in the districts of the west riding of Yorkshire the water is usually from 2 degrees of hardness up to 7 or 8 degrees, but 13 degrees of hardness is not a hard water as compared with many waters which are in use for domestic purposes in the country whose hardness would be from 30 to 40 degrees perhaps.

1457. I think we have it in evidence that what is commonly called hard water is anything in which there is 6 degrees of hardness, and that anything under 6 degrees would be soft?—That is a purely empirical standard, of course. I think the question of hardness would have a reference more to habit than anything else, at least what anybody would call hardness. Water with 2 degrees is certainly soft, and water with 18 or 19 degrees is certainly hard; but whether water should be called hard when it is 10 degrees, or when it is 13 or 14 degrees one could hardly say. There is a great advantage in the water which is 2 or 3 degrees over the water that is 12 or 13 degrees, like the water of London at this moment.

1458. Do you consider that water, which is, as you say, 2 or 3 degrees, much more healthy or more economical?—It is more economical. It is exceedingly doubtful whether it is more healthy, because people are in the habit of drinking waters of 17 or 18 degrees of hardness without any apparent injury to health; indeed, they are the most beautiful waters as drinking waters. The waters that are the brightest and the most liked are the hard waters, the chalk waters.

1459. Have you analysed any of the waters in the northern part of Scotland?—No, not to my knowledge; not of late years at all events. I think that the question of the effect of hard waters upon health is quite an open one. There is no reason to believe that chalk water is injurious except, I believe, in some instances, such as in the introduction of goitre. There are cases I believe in the valley of the Thames in which hard water is said to produce that effect; but the advantage of soft water for domestic use is very obvious, both in comfort, and also in economy, and for cooking purposes. So again for all purposes where steam boilers are in use soft water is much more economical, inasmuch as the boilers do not get foul.

1460. If you had your choice to provide a large community with water, and you were able to get with equal ease hard water or soft, you would prefer the soft water?—Undoubtedly. I should go further than that, and say that water that is hard ought to be softened if it is possible to soften it.

1461. (*Mr. Prestwich.*) Do you mean for genera purposes, excepting the question of health?—No, I do not attach anything one way or the other to the question of health, that is to say, where the hardness is in moderation, where carbonate of lime is the hardening ingredient. But where you have water with 80 or 90 grains of sulphate of lime in a gallon, as you sometimes have, that is another question entirely.

1462. You would consider, would you not, the presence or the absence of organic matter to be the essential point?—Yes, as far as health is concerned, I should.

1463. According to your analysis the Cumberland waters show a very small quantity of organic matter?—Yes, that is so.

1464. (*Chairman.*) What portion of organic matters is there in the waters which are supplied to London?—They differ at different times, but they are very much more considerable than those in the lake district. We have the records of Dr. Frankland's analysis as published by the Registrar-General, from which it appears that they are generally rather above one grain in the gallon, and sometimes considerably above one grain. The waters of the lakes are a little below half a grain—one of them is above half a grain.

1465. (*Sir B. Phillips.*) How many degrees of hardness are the lake waters?—Haweswater is 2 degrees of hardness, Ullswater 2·1 degrees, and Thirlmere 1·5; those are as soft as any natural waters are.

1466. (*Mr. Prestwich.*) Do you find those waters well aërated?—Yes.

1467. You have not given the quantity of oxygen, have you?—No, the quantity of oxygen has not been determined.

1468. (*Chairman.*) How much water, in an analysis such as you have made, is necessary to enable you to come to a satisfactory conclusion?—From two to four gallons, or you can do with less even.

1469. Are you able to say whether those waters were taken at any one particular time or at different times?—They were taken at one time. I know nothing of the collection of them; they were forwarded to me.

1470. You only know that a certain quantity of water was given to you?—Just so; they reached me at one time.

1471. They were stated to come from those places, and you analysed them?—Yes.

1472. And this is the result of your analysis, which may be found in the 13th page of Mr. Hemans' and Mr. Hassard's pamphlet?—Yes.

1473. And your opinion is expressed in a letter which accompanied them, dated March the 21st, 1866, addressed to G. W. Hemans, Esq., at page 14 of the pamphlet?—Yes.

1473*a*. Will you have the goodness to hand in your analysis and the accompanying letter?—(*The witness delivered in the following tables*):—

GRAINS PER IMPERIAL GALLON.

	River Lowther.	Haweswater Lake.	Ullswater Lake.	Thirlmere Lake.
Lime	1·54	0·50	0·81	0·42
Magnesia	0·50	0·18	0·20	0·14
Soda	0·80	0·71	0·51	0·46
Chlorides of Sodium and Potassium	0·48	0·40	0·69	0·77
Oxide of Iron, Silica, &c.	0·50	0·25	0·20	0·05
Sulphuric Acid	0·51	0·51	0·37	0·44
Carbonic Acid	2·05	0·82	1·03	0·56
Organic Matter	0·62	0·62	0·35	0·77
Total Impurity	7·00	3·99	4·16	3·61
Hardness before boiling	5·2°	2·0°	2·1°	1·5°
Hardness after boiling	4·4°	1·8°	2·1°	1·5°

These substances are probably combined as follows:—

GRAINS PER IMPERIAL GALLON.

	River Lowther.	Haweswater Lake.	Ullswater Lake.	Thirlmere Lake.
Carbonate of Lime	2·75	0·90	1·45	0·75
Carbonate of Magnesia	1·05	0·36	0·42	0·29
Carbonate of Soda	0·70	0·56	0·40	0·20
Sulphate of Soda	0·90	0·90	0·65	0·78
Chlorides of Sodium and Potassium	0·48	0·40	0·69	0·77
Oxide of Iron, Silica, &c.	0·50	0·25	0·20	0·05
Organic Matter	0·62	0·62	0·35	0·77
Total Solid Matter	7·00	3·99	4·16	3·61

106, Leadenhall Street, E.C.,
March 21st, 1866.

DEAR SIR,

I ENCLOSE the analyses of the waters of the river Lowther and of the three lakes, Haweswater, Ullswater, and Thirlmere.

As might have been expected, none of them show more than a small proportion of solid matter per gallon; the river Lowther is the least praiseworthy on this account, though even that sample contains only seven grains of total impurity per gallon.

The proportion of organic matter in all the samples is small; the water of the river Lowther is, however, slightly coloured, no doubt from peat.

The waters of the three lakes are as soft as any natural waters can be; the water of the river Lowther does not equal the others in this respect, but as compared to the usual towns' supplies, would be considered a soft water.

On the whole, I have no hesitation in saying, that any one of these waters, or a mixture of them, would be admirably suited for the domestic supply of town populations, whether large or small.

I am, &c.

G. W. Hemans, Esq., C.E. J. THOMAS WAY.

Professor J. T. Way.

7 March 1867.

1474. Have you seen any reason to alter the opinion expressed in the tables?—None at all. I might add that upon the river Lowther there are some lead mines in the immediate neighbourhood of Ullswater, and those samples were tested for lead, and that should have been so stated in the letter sent to Mr. Hemans; they were tested for lead with a view to ascertaining any injury that might arise from that cause, but lead did not exist in those samples.

1475. (*Sir J. Thwaites.*) But the washing from the lead mines passed through the lake, did it not, before it arrived at the point where those samples were taken from?—I do not know how that was. The lead mines are not on the river Lowther, and it seems that the river Lowther is not subject to the action of the lead at all.

1476. The water from the washing of the lead is discharged into the upper part of the lake, and traverses the whole lake, does it not, before it arrives at the river Lowther?—Yes; however, I can speak to this, that it does not exist in any of the four waters. The sample in question, I am informed, was taken in the middle of the lake.

1477. (*Chairman.*) In fact, in the four samples which were sent to you, you did not find lead to exist?—No.

1478. (*Mr. Prestwich.*) That water was collected in January; have you any reason to suppose that the quality of the water would differ according to the seasons of the year?—No, I fancy not; probably it might be a little more discoloured with peat at some times of the year than at others, for instance, in the late autumn or the winter.

1479. (*Col. Harness.*) How small a quantity of lead would your process have detected?—I cannot tell you, but it would be extremely small; anything that would be likely to be prejudicial to health would be readily detected.

1480. (*Sir J. Thwaites.*) Do you anticipate any improvement or deterioration in the value of the water in consequence of the mode of conveying it to London through tunnels, aqueducts, and so on?—I have not inquired into that question, but I should think not. I cannot see why the water should suffer from that cause.

1481. (*Chairman.*) Have you ever analysed any of the waters which are found in the district of North Wales, which Mr. Bateman's scheme proposes to take?—I have not analysed those which are spoken to in Mr. Bateman's pamphlet.

1482. Have you ever analysed the waters in that district?—I examined the water in Bala lake some years ago, but I could not speak authoritatively of any of those waters. I have had a large experience in the analysis of waters throughout the country.

1483. Should you say, speaking generally, that the waters in Wales would resemble very much the waters in the lake district?—I should think they would. The analysis would speak for itself, but waters flowing from different geological strata, of course, would differ in composition.

1484. Have you formed any opinion as to what would be the best geological strata from which to obtain water?—That depends upon whether you have reference to any particular town or are merely speaking in the abstract.

1485. Taking it in the abstract, what should you say?—I know of none like the millstone grit.

1486. When you say "any particular town," what do you mean?—Not having reference to this particular inquiry, I should say that the best geological district which I know for water supply is millstone grit, but that answer would not apply if you wanted to bring water from millstone grit to London.

1487. Taking it in the abstract, if you wanted to find out the best water, where would you go?—The waters in the district which we have been examining on the Rivers Commission, viz., those of the West Riding, are the best waters naturally. They are the foulest waters in the kingdom as they stand at this moment, but naturally they are the most beautiful waters I have ever met with.

1488. (*Mr. Prestwich.*) Of what degree of hardness are they?—The springs in the hills are under two degrees of hardness.

1489. Have you any reason to suppose that waters so soft as those would act upon the pipes?—That is a very doubtful question. I do not think that these waters would, but my answer would be that there should not be any leaden pipes to be acted upon.

1490. But how would it be with regard to their action upon iron pipes?—All water, whether hard or soft, will act upon the pipes if they are alternately full and empty, and soft water will act very rapidly upon iron pipes under such circumstances.

1491. (*Sir J. Thwaites.*) Take leaden piping, for example, which is constantly charged; would not it become coated very soon, and the lead be protected by the oxide?—Yes, that is so; but in the case of leaden cisterns you have the action, of course, at the surface of the water, where the air has access to the lead at the same time.

1492. (*Col. Harness.*) Is water which is kept in an open iron cistern injuriously affected by the iron?—I think that iron cisterns are apt to rust if they are not covered with asphalt. I have known cases where iron pipes with soft water have been entirely destroyed in a year or two from lying on the side of a hill where they were alternately empty and full, in fact, half full and half empty.

1493. (*Sir J. Thwaites.*) You would not think that a little iron was objectionable to the human frame, would you?—Not for drinking purposes; the pipes are injured, but the iron does not get into the water; it rusts into oxide of iron, which makes the water turbid, but it is not dissolved.

1494. (*Mr. Prestwich.*) Has it not been found that in some towns the iron pipes have had to be renewed in the course of a few years from the action of water upon them, as, for instance, in the case of Grenoble, where I believe that occurred?—I believe that it is quite likely, but in those cases, I think, it would be found that the water is not supplied upon the constant system, and that the pipes are not always full of water. I can mention a case which actually occurred with the water of the Surrey sands, the Bagshot sand at Farnham. A friend of mine, Mr. Paine, laid down water from some moor or common land above Farnham, to supply the town, and iron pipes were used. The water came down very freely, but the pipes, which were three or four inch pipes, were only partially filled, and in two years they were entirely destroyed by the soft water. You might consider that there was a current of air passing up the pipes at the same time that the water was coming down and the action of the air and the water together destroyed the iron. It is a well-known fact that iron in an unprotected ship is destroyed much more at the water line than it is either above or below.

1495. (*Sir J. Thwaites.*) I presume that the oxidation would not go on if the air were excluded?—If you

Professor J. T. Way.

7 March 1867.

put a piece of iron into aerated water, and seal it up so that no fresh air can get in, the oxidation goes on to a certain extent and then ceases altogether. The iron has no power of acting upon the water to get oxygen, but only on the air dissolved in the water. I believe that the constant supply system would be the corollary of the soft water and iron pipes.

1496. (*Mr. Prestwich.*) If it removed the oxygen from the dissolved air would it not render the water less suitable for drinking?—Yes, but it takes from and it does not add. Iron pipes are becoming now very constantly adopted in water supply. In this last week I have bought a house at Kensington in which every pipe in the house is iron; there is not a leaden pipe in the house at all.

1497. But in your case is the water comparatively hard?—Yes, but I should not fear any injury if soft water were substituted, providing that the air is kept out of the pipes. The air that is in the water would not do any substantial injury to the pipes.

1498. Though it may not injure the pipes would it not be likely to injure the water by the removal of that which constitutes an essential element in good drinking water?—You could not have the one without the other. If you remove the oxygen it would be by oxydation of course, and therefore the pipes would *pro tanto* be injured, but I should not fear that. One advantage of soft water would be the necessity for caution against lead; that is to say, we should get rid of lead as a means of supplying water which I think would be very beneficial indeed.

1499. Have you had much experience with regard to the desirability of using soft water for manufacturing purposes in preference to hard water?—There is no doubt great advantage in soft water for most manufacturing purposes.

1499*a*. Could you name the trades in which you would consider soft water preferable?—In trades of which I have seen a great many examples lately, in Yorkshire, for instance in dyeing, they prefer soft water to hard water, in fact, I presume, they went there for the soft water, and for washing the goods after dyeing; the quantity of soap consumed is immensely large even now in Yorkshire. A manufacturer will use as much as 1,000*l.* worth of soap in one mill in a year, and if he had hard water he would use perhaps 2,000*l.* or 3,000*l.* worth, and that has a very serious effect upon the price of goods. Soft water is not good for brewing; it is good for the darker kind of beers because a larger extract is obtained by it, but it will not brew bitter ale or light coloured beers, in fact, all the Burton beers are brewed with hard water.

1500. (*Sir B. Phillips.*) Is soft water desirable in London for the porter brewers?—I should think it was. It is only undesirable so far as colour is concerned; there are some waters which produce beer of a dark colour. I remember the case of a brewer who had been making beer of a moderately light colour, but having a necessity for more water, sunk an artesian well. Artesian wells coming from the chalk generally have some soda in them, and when he began to brew with the water from this artesian well he got a very large extract as it is called, that is to say, he got a great quantity of material from the malt, but the beer was so dark that it was unsaleable. In the case of porter brewing the quantity of extract is the real thing which is desired, but in the case of pale ale brewing the colour is the essential point.

1501. Have not the London brewers some material with which they colour their beer; it is not naturally of the dark colour that we see it, is it?—It is the colour of the very highly dried malt which gives it the black colour; it should be so, and I suppose it is so. The organic matter in the malt is half way between its ordinary state and that of real charcoal. It is not charcoal or it would only give an insoluble colour, whereas porter if filtered still remains dark coloured.

1502. But the malt is charred is it not in order to produce that colour?—It is heated strongly; in fact it is like burnt sugar.

1503. (*Chairman.*) Do you think that soft water would save the brewers the trouble of that charring operation?—No, it would give them a greater strength of beer extract, so to speak, from a given quantity of malt and the colour would not be objectionable, but it would not make the dark colour of porter.

1504. (*Mr. Prestwich.*) With regard to dyeing, is it not also very much a question of economy in the saving of soap rather than in the colouring of the dyes, as would appear to be the case at Lyons, for example, where the dyers use water of a considerable degree of hardness, and when it was proposed to give them softer water they preferred to use the harder springs which contained a larger proportion of carbonate of lime?—I believe that in the case of some of the bright colours a harder water is preferable, and for the very same reason that it is for beer, namely, that the lime precipitates some of the darker colours. Hard water makes considerably better tea than soft water. That is not the general impression; the impression is that soft water makes a stronger tea. It certainly makes a darker coloured tea, but you get a much better flavour from tea made with hard water. I should, perhaps, have qualified what I have said about dyeing, by saying that for the dyeing proper, especially in light colours, hard water is not objectionable, but I refer to the process taken as a whole. The washing requires so much water that should be soft that on the whole soft water is infinitely preferable.

1505. With regard to tea, we have been told that there is great economy in the use of soft water for tea; do you agree with that?—In saying that that is not so, I should, of course, contradict every practical person; most women would tell you that soft water makes the best tea. It does not make the best flavoured tea by any means, because soft water dissolves a quantity of bitter extract which makes the tea strong—but to a refined taste hard water makes the best flavoured tea.

1506. You think the tea would go further, but would not make so pleasant a beverage?—Not so refined a beverage; it makes a darker coloured tea and satisfies the wants of persons who can only afford a certain quantity of tea.

1507. (*Col. Harness.*) Is there some particular quality in tea which is drawn out by one water and left by the other?—Yes, it is a peculiarity of lime salts, aluminous salts, and some others to combine with the tanin, and the bitter principle of tea, and other matters of that kind, and to separate them from the solution.

1508. (*Chairman.*) You think that hard water brings out a better flavour and that the colour is merely a matter of fancy?—It is the flavour that the hard water leaves behind undeveloped that is really the difference between the two; the soft water dissolves a great deal more of the tea. It dissolves the same bitter matter in the first instance which you get in all cases when the tea has stood very long. Everybody knows that to taste tea in perfection you should taste it as the tea tasters do, that is, by pouring boiling water on a good deal of tea and pouring it off immediately. If you leave the water long on the tea it dissolves the bitter matter, and soft water dissolves the bitter matter more rapidly than hard water. It is not in the flavour that it gives, but in the objectionable flavour which the hard water leaves behind and does not give that the advantage consists; soft water dissolves the objectionable matter, whereas hard water does not.

1509. (*Sir B. Phillips.*) It is what is commonly known as the rough flavour which soft water extracts from the tea, is it not?—Yes, the active principle of tea is dissolved by soft water or hard water equally; that is to say, the principle which has the exhilirating effect.

1510. If people were to take tea in the same way that tea tasters do, you think that it would be necessary that it should be made with hard water?—Yes.

1511. Soft water would not have the same effect?—No. Soft water would give the true aroma of the tea, but it would be mixed with the bitter principle.

1512. (*Sir J. Thwaites.*) If your principle were to prevail our grocers bills would increase very rapidly I presume?—Yes; I know perfectly well that soft water is considered to be a great advantage for making tea, but it is not so for those who can afford to make tea good.

1513. (*Sir B. Phillips.*) That is to say, when you use hard water you want a large quantity of tea to give the same strength?—The drinking of tea is a conventionality like many other things, and people are accustomed to taste the bitter taste of tea and are satisfied with it.

1514. And that is extracted by soft water more readily than by hard water?—Yes, but if you wished to enjoy the flavour of tea you would make it with hard water.

1515. (*Sir J. Thwaites.*) If you want to catch the fine flavour of tea you would make tea with hard water, but if you consider economy you would use soft?—Yes, because the tea looks stronger and tastes stronger; it is not stronger for the object for which you really take tea. Tea and coffee have both an active principle, which in tea is called théine. It is a crystalline substance, like quinine, and whether it be hard water or soft water you dissolve that principle, but along with that principle, which is the really effective agent in tea on the animal economy, you dissolve other things which you might just as well leave behind, so far as the effect on the digestive organs is concerned.

1516. (*Chairman.*) Good tea, plenty of it, and hard water is your principle?—Yes; the saving of soap from using soft water cannot be denied for a moment, and also the saving of linen. The clot produced by lime attaches itself to calico and linen and to ordinary things which are washed, and tends to injure the fabric very much.

1517. (*Sir J. Thwaites.*) Was your attention turned to the process of scouring cloth when you were in Yorkshire?—Yes, a good deal.

1518. Are they not obliged to use a large amount of soap for the purpose of getting rid of the greasy matter?—Yes, and a great deal of that they recover now, but not so much as they should. In many mills in Yorkshire there are contractors, who take the soapsuds and add acid to it and get the grease back, and we were informed that upwards of 100,000*l.* worth of material a year is so saved in the West Riding.

1519. Soft water in that case would therefore be a matter of the first importance?—Yes. I believe the manufacturers of Yorkshire went to the different streams in the valley of the Aire and the Calder solely for the soft water. No doubt the supply of coal had some influence with them, but the trade settled itself down there principally on account of the bright, clear, and soft water. If it had been a question of coal only they would have gone into Staffordshire, but it is water that they want more than coal, and they have actually killed the goose that laid their golden eggs, because the water of many of their streams has been rendered so foul by these processes that they cannot use it for washing purposes. They do in some cases, but they get as much water as they can from wells and town supplies, which are derived from other sources than those streams upon which the mills are situated.

1520. Is there a general desire on the part of the manufacturers of that district for an independent supply of soft water?—I think they would like an independent supply, for they get it at great expense, and they must always have it. The tendency of the manufacturers is to go over each others heads up the streams; that is to say, if there be a portion of a stream with pure water (not for water power but for use in the manufacture) a man goes past his neighbour and locates himself, if he can, higher up; but that has almost come to an end. They have their mills along the little rivulets and streams up to the very tops of the hills, and it is difficult to say where they are to go for larger supplies of water for manufacturing purposes whilst they are so thickly populated on their own streams.

1521. Supposing a supply could be obtained from the lake district, would it not be desirable for manufacturing purposes and the health of the inhabitants?—I think that the remedial measures should rather begin at the other end; that is to say, to prevent the fouling of rivers by their processes, and it is upon that that our hope of doing any good in Yorkshire is founded. For the purposes of the manufacturer the streams would be sufficiently good if attention were paid to preventing the pollution by each manufacturer.

1522. How are they to get rid of their washings?—That is a problem which is under our attention at this moment. I have under my control, as one of the Commissioners, some experiments at Huddersfield, in which we are taking the black dye liquid, which is as black as ink, and endeavourirg to get rid of the discolouration.

1523. Have you tried the sump system of subsidence?—It has been tried in one or two cases, but very unsuccessfully. The black dye water is discharged in many hundred thousand gallons from mills; in fact, a little mill will discharge more than 3,000 gallons a day quite as black as ink into the river. Some attempts have been made to let it subside, and to run off the clear liquid. Mr. Ripley, who is a very large manufacturer at Bradford, gave us evidence on that subject He has large tanks, in which he allows a certain amount of this material to subside, and the water flowing over goes to other mills for other general use. But that is not successfully done in any case; the difficulty is to know what to do with the sludge when it has subsided. Mr. Ripley, after collecting it for a fortnight, sends it all out on Saturday afternoon into the river, so that it is merely concentrating it for the sake of getting clearer water during the interval.

1524. So that all the local streams are polluted?—Yes; there are very few streams that are not seriously polluted.

1525. Does not that condition of things render it necessary that they should have an independent supply?—If it is not wandering from the subject, I may say that we have the fullest hope that we shall enable each manufacturer so to deal with the water which he takes in, and which he fouls in his operations, that the rivers shall be fit for their use.

1526. Do you mean for domestic purposes or for manufacturing purposes?—For manufacturing purposes; hardly, perhaps, for domestic purposes. But it is a remarkable fact that the water in the rivers of the rivers of the West Riding of Yorkshire, when filtered, is exceedingly good water, in spite of all the contaminations that are thrown into them. I am engaged at this moment in making practical experiments to separate the solid matter of the black dye water; a little lime is added, a couple of hours subsidence takes place, and the water is as clear as water. There is a slight tinge of yellow in it, but it is perfectly fit to be thrown into the river.

1527. You precipitate, do you, all the matters in suspension?—Yes.

1528. How do you deal with that which is in solution?—The matter in solution is really unobjectionable, as far as the rivers are concerned; I do not mean for domestic purposes; but manufacturers say that if that water is thrown into the river, the black stuff being kept out, they will be able to use the river water, and that of course will liberate a great quantity of water for domestic purposes. The competition between the manufacturers and domestic necessities at this moment leads to a high price for both waters.

The witness withdrew.

B. Denton, Esq.

7 March 1867.

BAILEY DENTON, Esq., examined.

1529. (*Chairman.*) You are a member of the Institute of Civil Engineers and have had extensive experience, have you not, for upwards of 25 years in drainage, &c., in various parts of England and Wales?—I have, and it is in consequence of that experience, which has made me acquainted with nearly every river basin in England and Wales, that I venture to present myself to this Commission as a witness with regard to the subject now before it. The effect of drainage, as developed in my own proceedings, bears very largely, as everyone must admit, upon the question of water supply; and as there is a great change taking place in the country by the drainage of lands and the drainage of towns, the one in affecting the quantity of water and the mode in which it is discharged into the valleys and into the rivers, and the other in polluting the waters of rivers, it must be obvious to everyone that the effect on the water supply from both causes must be equally great. In the course of my proceedings in connexion with drainage I have become much impressed with the great importance of water supply (I call it water economy) to the country generally. I am led to infer from the attention which is now being expressly called to the supply of large towns that a very disadvantageous influence will be experienced upon the supply to small ones, and it was in order to lead the authorities of this country into the consideration of the whole subject that I have been induced on more occasions than one to speak of the change taking place.

1530. Before you go into that allow me to refer you to the paragraph in our Commission which directs us what our inquiry is to be and which excludes from it everything but the metropolis and the larger towns?—I do not propose to dwell upon the supply to any of the smaller towns, though I do wish to show that even with respect to the supply to the metropolis and the supply to all towns, large as well as small, drainage in its various phases is having its effect, and as you are dealing with the metropolis which is now supplied with water from the Thames and its tributaries which are and will be more largely affected by drainage, I should hardly think that you could exclude that subject from your inquiry, but if you think otherwise I have no desire to intrude my opinion upon the Commission.

1531. At present our duty is to ascertain what supply of unpolluted and wholesome water can be obtained by collecting and storing water in the high grounds of England and Wales by the aid either of natural lakes or reservoirs at a sufficient elevation for the supply of the large towns?—I observed that, and in my addressing your grace upon the subject, I felt some doubt whether the views that I entertained would be acceptable to this Commission.

1532. It is not a question of what is acceptable to us, but we are appointed to perform certain duties which are laid down by the terms of the Commission and we are bound to inquire only into the matter which is referred to us?—Would the Commissioners permit me to explain how far I think that the question submitted to you has reference to the points that I would touch upon. I am prepared to show that the upper streams of the Thames basin, the tributaries of the Thames, are capable of supplying the metropolis if supplemented by storage, and that that storage would partly consist of the water of under-drainage and the water of drainage by arterial improvements from the upper lands which form the margin of the Thames basin. I should state, however, that my proposal is to take from the Thames and its tributaries, at points above which water may be obtained in positive purity by the proper exercise of conservancy, all that may be required for the supply of London, having stored in winter the surplus waters of that period of the year in order to repay the river system in summer what may be required to maintain it at a fixed standard height.

1533. What is the height of the ground above Ordnance datum from whence you would get this water?—The height of Lechlade, which would be the highest point from whence the collecting conduit would start to bring the water from the high grounds to London, is about 210 feet 6 inches above Trinity datum.

1534. Could you give us the Ordnance datum?—It would be 12 feet 6 inches below that. If you consider that 222 feet 6 inches, being the highest point from whence the collected waters would start, is not the high ground referred to in the terms of the Commission, any information that I may convey or any opinions that I may express are of course beyond the inquiry.

1535. The Commission have been proceeding throughout the inquiry on the supposition that the water when it reaches London must be at a height of 200 feet?—As the point from whence my collecting conduit starts is only just about that height that condition cannot be fulfilled within the Thames basin, but if I can show you, as I hope to show you, that there is an ample supply within the Thames basin, then the question of quantity will be satisfied. The quality, with regard to hardness, is a point to which I might speak, but it is not the point upon which I wish to lay the greatest stress, because there are chemical means of overcoming hardness if it be considered a *sine quâ non* that the hardness of the Thames water should be overcome.

1536. You start by your highest point being 210 or 212 feet above Trinity datum; what is the distance from London?—The distance is 127 miles, the fall being something like 20 inches per mile.

1537. And is the height when you get to London to be 200 feet?—No; I look upon the question of high service to be one quite apart from the question of the source of supply, and one upon which the water companies must satisfy the just demands of the public.

1538. (*Sir J. Thwaites.*) You start at an elevation of 212 feet and you give an inclination of 20 inches per mile; at what level would the water be when it arrived in London?—I propose to deliver the water that I bring down to the present water companies at Hampton for them to raise to high service reservoirs, and so gain the same service as the projects which have been laid before you would gain by gravitation.

1539. Then in point of fact you would employ mechanical means to lift the water in any case?—Exactly so.

1540. And to distribute it to any part of the metropolis?—By such means it would be distributed I believe in a more economical way having regard to the first cost as well as to the mode of delivery. I believe that by raising the water delivered at Hampton to different parts of the metropolis at the required height for the localities surrounding them you would do it equally well, and more economically than by bringing water either from Wales or from Cumberland to a height varying from 250 to 270 feet and from those points to connect the water with the service of the metropolis.

1541. We first want to get the facts of and then the comparison between the two schemes, what in point of fact would be about the level of your water supply?—It would be at Hampton from 10 to 20 feet above Trinity datum.

1542. Have you calculated the height that you would have to raise the water so as to command the houses in the higher parts of the metropolis to give a sufficient pressure?—A contour map of the metropolis would show you the parts of the metropolis which would be served at different heights.

1543. What is the highest?—To place the companies' services at Hampton in the same position as the delivery from Cumberland or Wales, that is from 250 to 270 feet above datum, the water would necessarily have to be raised by steam power from Hampton

on the west, or from Old Ford on the east of London to the height of 250 or 270 feet.

1544. Is 200 feet your highest point?—No. It is a mere question of power to what height you would raise the water, but there is a very large proportion of the metropolis which is under 100 feet. In the proposal I am about explaining I have gone into the question simply to show, as I can incontrovertibly, that there is capability of supply within the Thames basin, if storage be resorted to.

1545. (*Chairman.*) For the moment, going back to the gathering ground where you propose to start from and without reference to the height at which you would require to deliver it in London, what capabilities are there in that district in your view for collecting and storing water, Lechlade being as you have told us your highest point?—I gave Lechlade because it was the head of the conduit which would collect the waters from the higher grounds of the Thames basin.

1546. (*Col. Harness.*) Is Lechlade the outfall of your gathering ground?—It is the highest outfall of the gathering ground, which is coextensive with the Thames basin itself, reduced only by the height necessary for collection. I propose to make each tributary stream a means of bringing from the drainage area of that stream its quota of supply to a main channel, which main channel will start from Lechlade and deliver its waters so far as the west side of London goes to the several water companies works at or near Hampton, and to place that water upon the same level as the projects from Wales and from Cumberland, the water having been brought down to Hampton will have to be lifted by steam power to the various heights required for the districts in the metropolis.

1547. Leaving for a moment the question of lifting, I want to get first of all the ground where you would collect the water, the quantity of water that you would get, and the rainfall in that district?—I should be very glad to give that information. It is my object in coming here to lay those facts before the Commission. Why I touched upon drainage was, that drainage itself is a means of increasing the supply of water and we cannot exclude it from consideration. But to give some proof that there is water sufficient, I would just mention these facts to the Commission. The area of the water-shed of the Thames is 3,300,000 acres, the population we may take at 4,500,000, the average rainfall is 26 inches, the minimum is between 19 and 20 inches, and that minimum is disposed of in this way—3 inches support the perennial supply of the river, that is to say, maintain the river in summer at the ordinary height; taking 3 inches from 20 there remains 17, and of that 17 we find by information of various sorts that a very large share runs off to the sea in winter; but, beyond the fact that this accretion occurs when the rivers are full, there is another fact that whatever water is taken by under-drainage from the atmosphere it is so much positive increase to the river supply and as underdrainage proceeds so will the supply be increased.

1548. (*Sir J. Thwaites.*) Is that really so?—It is distinctly so, whatever is taken from the atmosphere goes to increase the supply to the rivers.

1549. My question had reference to the rainfall which finds it way into the earth, and which you drain off by means of pipes, and you allege that there is an additional flow into the rivers of that quantity of water?—I do not say that the whole is additional.

1550. Supposing it were not drained off and that the basin were full would not the rainfall upon it be absorbed or find its way off instead of being carried by your pipes?—The water falling upon a drained surface is absorbed by it and passes down to the drains and passes out by drains to the rivers. If the land were not drained the water would rest upon the surface and when that land was perfectly saturated the water would flow off the surface into the rivers, but a large quantity would be retained to be evaporated. Whatever diminution of evaporation takes place by drainage that quantity must go to increase the rivers. Experiments which have been rather largely carried out show that from clay lands 3 inches of rainfall is discharged while from a free soil which before drainage had been a sponge to hold the rainfall there is thrown off from 3 to 5 inches. I do not say that the whole of that is new water, but whatever proportion is rescued from the atmosphere and discharged by the drains must be new water; and the great fact bearing upon this inquiry is this that that discharge from the drains is all in the winter months. I am now speaking of clay lands, the discharge from free soils goes on very often through the summer. I have often adopted the practice when draining the clays overlying the oolite and chalk of digging holes or wells, called swallow-holes, and dropping the water of drainage down into these water-bearing strata, and the springs have been strengthened by the process. We originate springs by drainage of free soils; land that has never emitted water before is found to emit a constant flow of water from drains where the drainage is in free soils, but that is not so in clays. In draining clays the whole discharge is between the months of November and May. Now as that is discharged out of the ground into the valleys in winter it comes to the Thames when it is not wanted; and what I contend is this, that whatever water is thus thrown out by drainage from the upper marginal part of the Thames basin is capable of storage for supply to London. The quality of drainage water is sometimes objected to, but as I propose to use the stored water of winter as compensation to the river system for water taken out of the tributaries this objection has no force. Every inch of rainfall discharged from an acre of land yields 22,622 gallons, and as each person taking 30 gallons a day requires for the year 10,950 gallons, it follows that each acre discharging 3 inches of rainfall will satisfy at least 6 persons.

1551. Can that be additional water; is it not the case that that water is due to the rainfall to begin with?—Most distinctly so.

1552. Then that which you drain off is simply that which is absorbed by the soil and carried off by means of pipes?—Yes, exactly.

1553. But supposing there were no means of drainage at all and the basin were full would not that water find its way off in another form minus the amount of evaporation?—It would find its way off in several ways. When the land is perfectly saturated a part would flow off the surface, a very small proportion would ooze laterally through the ground into the rivers, and the rest would be evaporated and the water that would be added to the supply from drainage would be simply that which would be taken from the atmosphere by the reduction of evaporation.

1554. Then all the additional water that you are catching by means of your drainage is simply that which is not evaporated by being left on the surface; that is to say, all that you catch of additional water is that which you save from evaporation?—Exactly so, that is all. But let that be as it may, all the water that is discharged from drainage and from the surface of the ground by the improved system of outfalls which is taking place throughout the whole country being thrown down into the valleys in winter when the rivers are full, instead of being retained on the surface and in the ground for summer discharge, is capable of storage, and if the quality of the water be not that which is directly serviceable for supply, it can then be used for compensation to the river in summer.

1555. (*Chairman.*) The area you have given us in acres; could you denote it in any way by the names of places? Where would be the extreme point on the west or east?—The area that would be tributary to storage would be about half the watershed, and there are something like 3,300,000 acres which constitute the basin of the Thames.

1556. From what I understand you to say you propose to bring water from the north part of the basin?—No, I do not say that. I take the upper half

B. Denton, Esq.

7 March 1867.

of the whole basin of the Thames which contains 3,300,000 acres.

1557. From what part of that district do you propose to bring the water?—I propose to collect the water from the higher portions of the basin, that is from the oolitic sources on the north of the Thames, say from Cricklade to Oxford, and from the various streams rising in the chalk throughout the whole of the area of 3,300,000 acres. It is not possible to state the quantity of water discharged by springs from the water-bearing strata of the Thames basin, but it is pretty accurately known that, while 1½ inches of rain maintains the ordinary summer flow in the river from April to September inclusive, at least 4 inches runs off during the remaining six months from October to March inclusive, without taking into consideration excessive floods. The ordinary winter flow, in fact, compared with the ordinary summer flow is as 2½ to 1. No dogmas as to loss by evaporation and other causes touch this fact, which manifestly proves, when the discharged drainage water is taken into account, the capability of storing in winter all that can possibly be required for compensation in summer. I may here remark that, in considering the annual rainfall as an index of supply, a great mistake is often made owing to the fact that all published records give the quantity of rain that has fallen from the 1st of January to the 31st of December, thus cutting two winters in half. The meteorological year, in its influence on water supply, should commence at Michaelmas in the one year and end at the same period the following year, so as to include the whole of one winter and the following summer. It is the winter's rainfall that governs the summer supply. A close examination of the Thames basin will, I believe, show that the minimum quantity of winter's rain that has ever fallen between the 1st October and the end of March has been sufficient to maintain the proportion which I have stated.

1558. In point of fact you propose to collect your water from the whole of the Thames basin?—No, the height would not allow of that, but the proportion of the 3,300,000 acres out of which I think it might be collected is 1,500,000 acres.

1559. Will you first state distinctly the exact names of the places where you take your water from and then tell us whether you are of opinion that the water from your gathering area would be suitable for domestic purposes, having regard to the amount of cultivation and other polluting causes?—Your Grace has rather anticipated the description which I propose to give of the works, it was my intention to explain to the Commission, but answering your question in the best way I can I must say that it is not possible, as each tributary of the Thames will be a means of collection to particularize any parts. I can give you the names of the streams which would be made tributary, beginning with the Thames proper, we should then take the river Churn, the river Colne, the river Leach, and so on.

1560. Could you put in a plan with the districts from which you propose to take the water marked with any particular colour?—I have a plan which I brought with me, in order to illustrate my views in the clearest way (*producing the same. See Appendix V.*)

1561. (*Sir J. Thwaites.*) What we want to know is not the acreage of the water-shed of the Thames, in a large portion of which you could not collect your water at all, but you have your eye fixed no doubt upon some portion of that watershed from which you do expect to collect water?—Yes. If you will allow me to describe my plan in consecutive order all those facts will appear. For instance, I propose that the head of my conduit supplying London from the west should be at Lechlade.

1562. What we want as a starting point is, what area do you propose to utilize as the gathering ground of the water which you intend to bring to London?—All above the main trunk of the Thames.

1563. What acreage might that be?—I consider that the contributing space will be 1,500,000 acres, that is about 750,000 acres in the Upper Thames region, and 750,000 acres in the several other contributory areas.

1564. What is the condition of that 1,500,000 acres eliminating that from the other parts of the valley of the Thames?—The condition of that ground, speaking geologically, and looking to the furthermost northern part, is the great oolite formation. Looking to the other tributaries which do not rise from the oolite formation, you have the Kennet, you have the Colne, the Lee, and its various branches, all of which would be put under contribution, as I shall hope to explain to you.

1565. What is the surface condition of that district?—It is cultivated; highly cultivated in many parts.

1566. And of course subject to manuring and other processes?—Yes, it is.

1567. Can you suppose that from an area under the influence of that source of pollution you can get a supply of pure water for the metropolis?—Decidedly, because I propose to utilize for supply the waters which are collected by springs into the various tributaries which I have referred to, and which under proper conservancy may be perfectly purified, and kept so.

1568. I understand you that you have regard to the rainfall due from any area, amounting to 1,500,000 acres; but now you direct my attention to certain springs from which you propose to take your supply?—I propose to take the required quantity of water from various tributaries of the Thames, adding to their number as the demand for water increases, and compensating those tributaries for the water taken out of them by the collection of the surplus water from the surface.

1569. Do I rightly understand your answer to be this, that the primary source of supply is the springs?—The rivers themselves.

1570. The rivers themselves as the result of springs?—Yes.

1571. And the means of compensating those rivers will be the collection and storing of the rain-water?—Of the rain and drain water, the rain-water which swells the river principally, and the water that is brought down by drainage which is rain-water in another shape.

1572. In point of fact it is not part of your proposal to collect the rain-water due from that area, and bring it to London for the purpose of the inhabitants, but to intercept the streams that flow from the several springs that flow in that district?—I should take from each tributary as much water as those tributaries could supply, returning to them an equal quantity of water stored during winter.

1573. But are not those streams to which you refer fed mainly by the rainfall?—They are fed in some measure by the rainfall passing over the surface, but in the largest part they are fed by springs, which consist of the rain-water that has percolated through the oolite on the west, and the chalk on the east, and having passed through a great depth of soil rises again in springs and thus feeds the rivers.

1574. (*Chairman.*) Are not those rivers which you propose to put under contribution for your scheme now being made use of in the same manner by the existing companies?—They are; but the water collected from those tributary rivers is brought down by the main trunk to Hampton, where it is abstracted, and in their way partakes of the pollution which the main trunk suffers under from the sewage of the different towns on its banks.

1575. The existing companies have certain rights and powers over the districts in which those rivers are, and from which they take their water; how much water do you contemplate bringing?—The existing companies now draw out of the Thames at Hampton 60,000,000 gallons per diem, and they have power to extend that quantity, I believe, from 60,000,000 to 100,000,000; I propose instead of taking

the water as they do out of the main trunk of the river at or near Hampton, to take it out above the influence of contamination.

1576. Still their right to take it exists?—Yes, their right to take it exists up to 100,000,000 gallons per diem, I believe.

1577. How much do you anticipate taking per diem?—I propose to collect at once on the west side of London the 100,000,000 gallons which they ultimately have the power of taking.

1578. You propose to take 100,000,000 gallons, and they have power to take 100,000,000 gallons; do you propose that their power should be repealed?—No, my proposal would be simply to serve them with pure water instead of impure water as they now get it.

1579. Then is your proposal to take 100,000,000 gallons higher up, and give it to the companies, instead of them doing it for themselves?—I should propose to collect the water of the upper streams, compensating those streams by the surplus water, and bringing that pure water when collected down to Hampton, delivering to them by a channel, partly covered and partly open, from Oxford to Hampton or almost wholly covered, and to deliver to them the maximum quantity that they have now the power of taking out of the Thames after it is polluted.

1580. Then in effect for the powers which they have at present you would, speaking shortly, substitute yourself or your scheme. They take now 60,000,000 gallons per day, and they have power to take 100,000,000 gallons, and you propose that instead of their taking 100,000,000 gallons in the manner in which they do now, you should take the water some hundred miles further off, and take it down to them at Hampton, and give it to them, so you would do that which they have the power to do now?—Yes, but I should serve them with that which they have not got now, that is pure water instead of impure.

1581. But supposing that they think that their mode of collecting it is a good mode, and that they object to having 100,000,000 gallons abstracted from their gathering ground until you could show that you had the power to get another 100,000,000, do you think that there would be enough for both?—No, I am proposing to be the medium of supply to the companies. I am proposing a scheme, in fact, by which the water companies can obtain a pure supply instead of an impure one, and a larger quantity of water without at all interfering with the river system.

1582. But that would necessitate a repeal of their existing Acts, would it not?—I have not considered that point.

1583. Without expressing an opinion as to whether it is right or wrong, it would be so necessarily, would it not, if they have the power now of getting 100,000,000 gallons, and you propose to supply 100,000,000 gallons to them?—I presume that the object of the present inquiry is to secure a better supply of water than is at present afforded to London, both in quantity and quality. If you will allow me, I hope to show that by supplementing the present supply with storage, you can get quantity, and by going to the upper regions of the different tributaries, and dealing with the question of pollution in the way which I shall hope to explain to you, you can secure quality. It is the failing in quantity, and the failing in quality, of the present water supply that I presume has originated this Commission.

1584. Putting it in this way—If the scheme which you are proposing to us now were carried, the water companies would not be able, would they, to exercise the powers which they have now under Act of Parliament?—Of course, if there was any company or any body to take up the project which I am now endeavouring to explain and supersede the companies, that would be so, but that is not my idea. It is to supply the existing companies with pure water

1585. Would not the effect of your scheme being carried out be that the existing companies could not enjoy the rights which they now have by their Acts?—I do not consider that the necessity for the enjoyment would cease.

1586. But the fact would be so, would it not?—I am not able to give an answer to that question. I am not evading the question, but I do not feel myself competent to give an answer.

1587. What do you suppose is the capability of the ground from which you propose to get the water—how many million gallons per day?—I have told you that I propose at once to collect 80,000,000 gallons, and to construct a conduit capable of delivering 100,000,000 gallons to the water companies at Hampton.

1588.—You propose to take 100,000,000 gallons, and the water companies have power to take another 100,000,000; do you think that the ground would be sufficiently large to produce 200,000,000 gallons per day?—The two things could not exist together—the one would supersede the other.

1589. (*Sir J. Thwaites.*) As I understand you, you constitute yourself a wholesale dealer, and you bring the water in volume from the upper part of the Thames to a point where it could be conveniently taken by the several water companies. Supposing when you had got your water there the water companies were to say, "No doubt you are a very intelligent engineer, and have given yourself a great deal of "trouble and expense in bringing the water here, but "we prefer to take it from this point in the Thames, "we have authority to take it, and we can, by a system "of filtration, produce good and proper water with "which to supply the metropolis," how do you get rid of their powers and rights?—If the public were satisfied with that, and the companies could do what you say they might propose to do, there would be no necessity for a scheme; but I am assuming, and I think upon good data, that they are incapable of saying so, or doing so. If the result of the present inquiry should be that the water companies are prevented from taking water out of the Thames when its volume at the place of abstraction has been reduced below a certain fixed height unless they give back an equal quantity, and they are further prevented from taking water out of the river into which the sewage of any towns above has been in any shape discharged when the quality does not come up to a fixed chemical standard, then there would be no further complaint on the part of the public. The companies would then necessarily resort to storage for compensation, and would thus maintain the standard volume through the metropolis, and they would ascend the river for the water of required purity should analysis show the supply to be defective in quality.

1590. Is it any part of your scheme to deal with those companies, because, if they do not take the water of you when you bring your water to that point, unless you yourself have a system of distribution to the metropolis independent of the water companies, the water would be of no value?—Exactly so. My scheme really consists in utilizing the upper streams of the Thames—not only those that rise in the oolite to which we have given the most of our attention, but those on the east, from the chalk, and those on the south from the Greens and Bagshot sand—utilizing those streams by taking pure water out of them, and returning to them an equal amount of collected surplus water. I am not prepared to do more than to show that there is a full sufficiency of water in the Thames basin, and that the quality may be, by proper conservancy, made so pure as to be equal, or nearly equal, to that which can be obtained from Wales or Cumberland.

1591. (*Sir B. Phillips.*) Do you propose to give to the water companies 100,000,000 gallons of pure water in lieu of 100,000,000 gallons of the impure water that they now deliver, or do you propose to give that as an addition, making together 200,000,000 gallons?—I propose to deliver 100,000,000 gallons to the water companies on the west, but I also propose to deal with the New River and the East London in a way that I should like to make plain to the Commissioners. There

B. Denton, Esq.

7 March 1867.

is a very large quantity of water to be gained from the chalk on the east as also there is from the oolite on the west. In addition to the streams from the Upper Thames and the Lea, there are, as the Commission are aware, the Kennet, the Coln, the Wandle, the Mole, the Wey, and various other streams, all of which may be put under contribution as the demand for water increases.

1592. It has been stated to the Commissioners that it would be of no use to entertain any scheme which would not deliver to London from 200,000,000 to 250,000,000 gallons per diem; how could you meet such a large demand?—If I am permitted I can show that the Thames basin is quite capable of doing that, but I would start by delivering 80,000,000 gallons to the companies taking their water supply from Hampton, and 40,000,000 to the New River and the East London, and the simple way in which I propose to do that is as I have stated before by utilizing the upper streams of the Thames and the Lea and repaying those streams by collecting the winter's surplus water.

1593. There are two conditions which it would be necessary to fulfil, first that the water should be pure, and secondly that it should be soft; would you deliver water both pure and soft?—There is a great deal to be said upon the question of softness which I do not think has yet been considered. I admit that a vulnerable point in the project which I place before the Commissioners is that the water will still be comparatively hard, but that the hardness of the Thames water will be greatly reduced by carrying out the principles which I have partly enunciated and which I wish further to explain is equally certain.

1594. (*Chairman.*) You have stated to the Commission that you propose to collect the water somewhere near Lechlade over an area of 1,500,000 acres will you tell us how you propose to take it?—At Lechlade the Thames and Severn canal joins the Thames, and higher up the North Wiltshire canal joins the Thames and Severn canal. I propose to purchase those canals and utilize them for the collection of the waters of the Thames above. Then passing down from Lechlade I propose to collect the waters from the various tributaries, the Coln, the Leach, the Windrush, the Evenlode, the Cherwell, and the Ray, making a concentrating reservoir just below Oxford.

1595. What would be the size of that reservoir?—That reservoir would not be a large one, it is to be only a mere concentrating basin.

1596. But what would be the size of it?—That has not been determined. In fact it is not necessary to refer to it at all as it is not a feature in the scheme. Then passing down from Oxford to London, the Ock would be in the same way brought under contribution, and the Thame, the Loddon, and the Coln. The points where I should propose to have my compensating reservoirs would be those that occur at the junction of the impervious bed of the Oxford clay with the oolite,—in point of fact that is the lowest point from whence these springs are emitted from the water-bearing strata of the oolite—and by having my compensating reservoirs there, I should be enabled to utilize and bring down the whole of the water required from the various streams into my collecting conduit.

1597. What size would that conduit be?—That conduit would vary in size telescopically as it would collect water from the various tributaries.

1598. How do you get the water into it?—The water from the upper portions of each stream would be brought down by a channel devoted to the purpose above the surface of the ground of the main valley, so that no flood water or polluted water could enter. Those channels would follow as near as practicable the lower courses of the tributaries, and would be in size apportioned to the quantity of water to be taken from each stream.

1599. Can you give us all these matters in detail?—I can explain it to you now; I am not prepared with any detailed estimate.

1600. Could you tell us what would be the quantity of water and what would be the size of the conduit?—The several quantities contributed by the tributaries I cannot tell you, as there is a total absence of gaugings of those streams. We only know at certain point upon the main trunk, after those various tributaries are collected, the quantity of water that passes down the Thames; that is all we do know; there is a total absence of reliable gaugings.

1601. (*Mr. Harrison.*) You would pass your conduit, would you not, above the level of all those streams at the point of crossing?—Yes.

1602. And that would give a sufficient fall so as to put the pipe across and bring the water into your conduit?—Yes. I should like to explain, if the Commission have sufficiently followed me and I have made myself intelligible, that on that plan which I have produced, the margin of the yellow gives the line of demarcation between the water-bearing stratum at its outcrop and junction with the Oxford clay. From that line to the main trunk the tributaries are mere conduits for the water which has been collected above, and I should propose to have my reservoir on each as near as possible to the junction of the two strata, taking pains by intercepting the sewage above to keep the streams as pure as possible, in perfect purity I would say, and making a reservoir there to hold the surplus water brought down in times of excess in order to repay the quantity of water taken out above. The whole surface of the country above the line of demarcation I have described, having absorbed the rain which maintains the springs, is obviously capable of absorbing any amount of sewage that may be utilized on its surface. If the Conservators of the Thames would compel the application of the sewage of towns above the line of demarcation to high grounds of a porous character, where it would act as the water of drainage, when dropped into swallow-holes, to increase the volume of the springs, the difficulty would cease, and such a plan must be preferable to irrigation on low meadow ground, where the effluent water, passing *over* instead of *through* soil, must always be charged with a certain proportion of sewage in solution, if not also in suspension. A study of the geological character of the upper portions of the Thames basin—the chalk and the oolite—will satisfy you that, maintaining as they do the river system of the Thames, they are capable of absorbing sewage to any amount, with benefit rather than injury to the springs themselves.

1603. (*Chairman.*) How do you propose to intercept the sewage?—I propose to intercept the sewage in two ways; for a certain distance up each contributing stream it would be by intercepting open drains; above that, and wherever, in point of fact, it would be more economical to do so, I propose, by compulsory powers over the towns and villages, to raise the sewage on to the hills so that there should be a complete absorption of the sewage into the soil.

1604. When you speak of by compulsory powers over the towns and villages, what description of powers do you propose to obtain?—The power to exclude sewage will exist, I believe, in two years from this time for the main trunk of the Thames. No town will be allowed after a certain date (I do not know the exact date) to discharge its sewage into the Thames; they must find some means of dealing with it other than the system now adopted, and I would suggest that the compulsory powers should be extended to the tributaries.

1605. What would you propose to do with the sewage?—To use it for irrigation above, though the mode of application would be different.

1606. How would you get at it, and what would you do with it?—The plan which I should propose to adopt for the higher towns would be that which is being carried out at Watford and Rugby, and in various towns and places where lifting is adopted. Where it would be conformable to the system which I am now explaining the sewage from the towns would be carried down to the meadows below by gravitation, and then thrown over the land, and the drainage of the irrigated lands passed down by an open channel to a point below the point from which we should take our water supply.

1607. (*Sir J. Thwaites.*) Where would be your point of discharge, because you are aware that you could not apply the sewage at all times of the year to the land, at times of cropping, for example, and in frost and snow, and there are a variety of conditions which would be a bar to your applying it to the soil?—That is an objection which has been often raised, but it is removed by the towns taking upon themselves a certain quantity of land, we will say one acre to every 100 inhabitants, and arranging the land in pasture and arable cultivation, by which plan the whole of the sewage may be applied all the year round.

1608. Supposing that you had six weeks of frost in the winter, what would you do with your sewage; you could not apply a gallon to the land in that condition, but there could be no stop to the flow of the sewage?—That could only occur in extreme cases, for by the diversion of the contributing streams in the way that I am speaking of you would do no injury to the water to be utilized for the supply of London if the discharge from the irrigated grounds or the sewage in its worst state were discharged below the point from whence you take the water.

1609. (*Mr. Harrison.*) Take such a case as Banbury, which is to be your northernmost point, how would you avoid the sewage from that place polluting some of the streams which would come into your conduit?—I should propose to exercise compulsory powers to oblige the town of Banbury to raise the sewage water to lands much above the river.

1610. Still the water from those high lands would drain down into the river, would they not?—It would if it were not intercepted by swallow-holes, which would at all times afford a simple remedy.

1611. (*Chairman.*) During part of the summer when the crops are coming up, would you not ruin the crops by covering them with sewage?—By using the sewage for grass land that would not happen, because you would continue to mow the grass green and have fresh land upon which to apply the sewage.

1612. Do you mean to make the corporate body of the town a sort of farmer?—That is the provision now made by Act of Parliament, every town in England will sooner or later be obliged to make such an arrangement as that. They must either lease the land or buy the land, or dispose of their sewage to the farmers to lift or gravitate.

1613. (*Mr. Harrison.*) Do you think that you could effectually prevent any sewage after being so used from coming into those streams?—I have given that point considerable attention. Going to the river Lee as an instance, which I should like to deal with particularly, I would put as a parallel to Banbury the town of Luton, which lies at the head of the river Lee, or nearly so. I should require that town to lift its sewage on to the hills above it, if they are chalk. There is a very mixed character of soil in the neighbourhood of Luton and the sewage might be lifted there 100 or 150 feet and put upon land which would absorb it. And then answering your question, I believe that by the percolation of that sewage through the 100 feet or more which it must pass through to get to the river, a perfect purification would take place.

1614. Does the Act of last session give power to compel parties to lift their sewage 150 feet?—No, I do not know that it does. I think that irrigation by gravitation was the principle most in view, but it must be extended if the required purification cannot be attained without lifting.

1615. But as it exists now any compulsory powers under that Act would be simply this, that you would use the sewage, and the water would then again come into the Thames?—I do not think that the Act prescribes the mode of application.

1616. I mean, that there is no compulsory power to compel them to lift their sewage to any given height?—Perhaps not; but the prohibition, if strictly exercised, would be sufficient of itself. No town could then discharge its sewage into a river in an impure condition, that is to say, it must undergo such a purification by irrigation or otherwise that the liquid remaining shall go into the river in a pure state.

1617. (*Sir J. Thwaites.*) Would the waters from the land so irrigated flow into your source of supply?—I propose that on the higher portion of these streams all the towns should be obliged to lift their sewage if the water cannot be purified, as I believe is the case, by irrigation at a low level. The difference of the effect in lifting the sewage and letting it pass by gravitation would be this, that the sewage would be lifted in the first case on to a high surface of porous ground which would absorb the sewage, and the depth between the surface of the ground to which it would be applied and the river would secure perfect purification; while in the second the effluent liquid after irrigation would pass into the river immediately.

1618. Have you examined the sewage water as it passes off after it has been used for irrigating purposes?—It would not be possible to distinguish the water that would pass through 100 feet of soil from that water which would rise in the ordinary nature of a spring.

1619. Have you examined the application of the sewage at Croydon?—I have not examined the application of the sewage at Croydon, but at Rugby I have, and in most of the instances where it has been applied.

1620. Although the water may run off completely, it does hold in solution, does it not, a good deal of matter which would be most offensive?—There is no doubt about that, where the sewage passes only over the surface, but it would be totally different if it passed through a porous stratum 100 feet deep.

1621. Notwithstanding your application of the sewage to the adjoining lands of the several towns on the rivers in order to prevent its flowing into and so contaminating the streams from whence you take your supply, will not the water find its way into your streams after it has done its duty in irrigating that land?—Yes, where it is applied by gravitation to riverside meadows or impervious soils, but I wish to be understood that I should propose to intercept all sewage water, whether it has been used for irrigation or not, and to discharge it below the point from whence I would take my supply.

1622. Then any water due from the area under irrigation would not find its way into your channel?—Not into that part of the river which would be utilized for supply.

1623. Have you made a section of your culvert or aqueduct by which you propose to bring your water the 127 miles?—The valley itself is the section.

1624. You propose, therefore, to bring this water in a given channel, and to exclude any source of contamination?—Yes, I do.

1625. In order to arrive at an estimate you have calculated, no doubt, the size of the aqueduct which would be necessary to bring the volume of water that you require for the supply of the metropolis?—Yes, I have.

1626. At what size do you begin?—The conduit from Oxford to Hampton would, in the same way as I have explained with regard to the upper conduit, gradually increase as contributions were made from the streams crossed between these points, which include the Ock, the Thames, the Kennet, and the Colne. The Wey and the Mole would have a separate system and would be added when the demand increased. They are capable, if the Bagshot sand district be added, of supplying from 30,000,000 to 40,000,000 of gallons daily.

1627. You would increase the capacity as you go along, but what do you start with?—It would be partly open and partly covered. Where it was eligible to have an open channel, it being cheaper, I would adopt it, and the size of that open conduit would be 12 feet 6 across, with a depth of 6 feet, and where covered it would be eight and a half feet circular.

1628. And you give to that, do you not, a fall of 20 inches to the mile?—Yes.

1629. That would render necessary a lining to the aqueduct, would it not?—Yes, it would.

1630. Of what material do you propose to line it?—

B. Denton, Esq.

7 March 1867.

Partly of concrete and partly of brick is what I have proposed.

1631. What proportion of the 127 miles is in tunnel?—About half the 90 miles from Oxford to London would be covered, and the part above Oxford would all be open.

1632. (*Col. Harness.*) When you speak of the other part being covered, you do not mean, do you, that it is to be in tunnel?—Approximating the surface. The sides of the open channel would be sufficiently above the surface to exclude the floods.

1633. (*Sir J. Thwaites.*) You merely cover it for surface convenience; it is not as if you were passing through a mountain?—No, I propose to cover it simply to keep out the pollution of the atmosphere.

1634. Of what size are your compensating reservoirs in the upper part of your gathering grounds?—The size of those reservoirs would be various, and they would agree with the quantity of water extracted from the several tributaries. Upon the whole, I consider that we should require on the west of London, that is to say, for the Thames, 2,720 acres of water surface, with 280 acres for banks to enclose the reservoirs, making together 3,000 acres.

1635. I presume that those reservoirs would be formed in convenient valleys?—They would specially be constructed on clay bottoms in the valleys, not in the way which is adopted in the higher hilly and mountainous districts of England; they would be formed on the flat, if I may use the expression; they would be entirely embanked by made banks, which I contend would be not only safer to retain the water, but less dangerous to the people below, being less in height. The height which I should propose to have the water in the reservoirs would be 20 feet—that is, from four to five feet under ground, and the remainder above, the depth below the surface being according to the depth of the streams to which those reservoirs would be addenda.

1636. Do you concrete the bottom of those reservoirs?—No, I have not proposed to do so. You observe that they would be compensating reservoirs, and would not be required for supply; the supply would be taken from the streams above.

1637. My question had merely reference to their capacity to hold water?—They would be made upon impervious soil.

1638. What would be the total expense of the formation of your reservoirs and of the conduit up to Hampton, giving a capacity equal to supply 100,000,000 gallons per diem?—I do not propose to make the reservoirs for 100,000,000 gallons on the western side at present. I propose to make the conduit sufficiently large to bring down 100,000,000 gallons, but the reservoirs, which would only hold six months' supply of 80,000,000 gallons daily in the first instance, would be increased in size and number as the supply was required to be increased. The cost of the reservoirs of which I have now given the figures, making, in the whole, 3,000 acres, would be 1,360,000*l.*

1639. Do you mean that 1,360,000*l.* will cover all your structural cost, including the price of 3,000 acres of land, and the compensation payable in respect of severance and easement, and so on, up to Hampton?—I am dealing now simply with the reservoirs, which would be in blocks, and there would be very little consideration due to severance.

1640. I want to know the total cost of your scheme, including such reservoirs as may be necessary to compensate the rivers for the water abstracted, the formation of your culvert, the cost of the land which you must purchase for that object, the easements, the severance, and all structural cost up to Hampton?—In my published paper I gave the total cost at 4,500,000*l.* I have increased that, because I have increased the size of the conduit from the 80,000,000 gallons capacity to 100,000,000 in the case of the Thames, and correspondingly on the Lee. I have increased that cost from 4,500,000*l.* to 5,320,000*l.*

1641. If I understand you rightly, then, this is only a part of a general scheme for the supply of water to the metropolis. Do you propose to deal with the New River?—I propose to supply the New River with pure water.

1642. But not from this source?—No, not from this source, but from the upper part of the Lee.

1643. You say that 4,500,000*l.* is to be the expense of this scheme?—No, it is the expense of the whole to supply immediately 120,000,000 gallons, with the capability of increasing the supply up to 160,000,000.

1644. You do not mean, do you, that the structural works would have a capacity given them to supply up to 160,000,000 gallons, but that 4,500,000*l.* is the expense which you would incur to supply 120,000,000 gallons?—Yes, with capacity in the conduits for the larger quantity.

1645. Then it is simply increasing the reservoir accommodation?—Exactly so, the only addition that would be necessary, would be to increase the size or multiply the number of the reservoirs.

1646. You increase that 4,500,000*l.* by what sum?—I have already increased the estimate to 5,320,000*l.*; the only additional cost to secure 160,000,000 gallons daily would be in the reservoirs.

1647. Then that brings the water near to London?—It brings to the works of the different companies the quantity of water that I have mentioned.

1648. I understand that that expense leaves us at the mouth of the tunnel; there is no resevoir at Hampton, and no head by which you could supply it to London, and that must be a separate expenditure, must it not?—Precisely so. The companies now raise the supply, and they will be obliged before long to furnish it at constant high pressure. I see that Mr. Bateman estimated the cost of lifting and filtering the present supply of water at 75,000*l.* a year.

1649. There is no filtering included in the present proposal?—No, he incidentally in his pamphlet stated that the present cost to the companies of filtering and raising the water was 75,000*l.*, I would increase that to 100,000*l.*, and of course if you multiply that by 20 years' purchase, it represents 2,000,000*l.* of capital.

1650. That is the cost of the pumping power necessary for the present supply?—Yes, 75,000*l.* is, and increased as I would increase it, it would be 100,000*l.*

1651. Would that give the quantity of water necessary for the supply of the metropolis for the next 10 or 20 years?—Probably not for the next 20 years, but it would be equal to supply 120,000,000 gallons daily, the present supply being 100,000,000 gallons. My proposal embraces three sources of supply with a means of future augmentation, viz., the upper sources of the Thames giving 100,000,000 daily, the Lee giving 60,000,000, the Wey and the Mole giving 40,000,000, making 200,000,000 daily, exclusive of the Colne and the Wandle, which with storage may provide a share at some future time.

1652. (*Col. Harness.*) Have you at all pitched upon the sites at which you would make your reservoirs?—Not definitely.

1653. (*Mr. Prestwich.*) You say, do you not, that at Lechlade the height of the reservoir would be 220 feet above the Thames at London?—Yes.

1654. Would it not be possible then to bring that water and deliver it in London by gravitation, following the course of the Thames valley?—No, it would of course at a certain cost be competent to bring the water and deliver it at a higher point than we now propose to do. If we started from Lechlade with a descending contour line catching the tributaries at the highest available points, the collected water might be delivered, perhaps, at 100 feet above ordnance datum; if we started from Cricklade, perhaps, at 140 feet; if we went higher still and could gain all that is wanted by pumping at Thames Head, we could deliver the water 150 feet above datum, but this is not likely.

1655. But independently of your own plan, could that water be brought a distance of 100 miles, and delivered in London at a height of a hundred feet?—Yes.

1656. (*Col. Harness.*) Of the 120,000,000 gallons, what proportion is receivable at Lechlade?—A very

small quantity; the least quantity would be there, because that would be the head of the system.

1657. You have not stated in figures, have you, what would be the proportion?—No, I am not prepared to state that.

1658. (*Mr. Prestwich.*) Could you give us some particulars with regard to the springs which supply those tributaries, and the quantity in the different valleys?—At present they are pumping 3,000,000 gallons daily out of the oolite into the Thames and Severn canal, of which the greater portion finds its way into the Severn, and not into the Thames, and one of my reasons for suggesting the purchase of the Thames and Severn canal was that that 3,000,000 gallons should be the first contribution to London, which would in fact be a restoration of the Thames basin to that extent.

1659. (*Chairman.*) How does that water find its way into the Severn now?—It is pumped out of the oolite by the Thames and Severn Canal Company into the canal, and is used for canal purposes towards the Severn.

1660. What would the Thames and Severn Canal Company say to your proposal?—It would be part of the project which I have laid before you to purchase the Thames and Seven canal. This water is pumped up to the summit of the Thames and Severn canal.

1661. Does the Thames and Severn Canal Company carry on any business?—It does, but as was mentioned in Parliament last year, it is in such a state that a small amount of money might purchase it.

1662. (*Mr. Prestwich.*) Do you know the quantity of water that flows down the Thames at Lechlade?—I do not. I have already observed that there is almost a total absence of any reliable gauging of the Thames and its tributaries, but we do know this from the evidence of Mr. Stacey before the Rivers Commission, and a remarkable fact it is, that the general summer average volume at Wolvercot, which is just above Oxford, is 73,000,000 gallons *per diem;* but in the dry summer 1865, it was reduced down to 62,000,000 gallons. But the winter flow is represented by very different figures. On the 2nd of January 1863 the quantity flowing down was 321,000,000 gallons, which is represented as the ordinary winter flow; it increased gradually in five days to 350,000,000, 430,000,000, 588,000,000, 636,000,000, 702,000,000, and 742,000,000, which was the highest it arrived at. I submit that that must go some way to prove the capacity of the Thames basin to supply water if the surplus be stored in winter, to compensate the rivers for what may be taken out of them in summer. It will be observed that Mr. Stacey represents the ordinary winter flow at Wolvercot as about $4\frac{1}{2}$ the ordinary summer flow instead of $2\frac{1}{2}$ times as I prefer to take it.

1663. Have you formed any idea of the quantity of water that you would get from the tributaries above Lechlade?—I have not, but there is a fact which is known to most engineers, and the Honourable Commissioner will perhaps be able to appreciate it better than I can, that 3,000,000 gallons are lost out of the Churn in a passage I think of five miles when passing over the oolite, and that quantity is not recovered again.

1664. You have noticed have you not, that in many cases where the springs rise in the higher tributaries as they pass over permeable beds, the stream loses a portion of its volume?—That is the case with the Churn. The Churn was gauged very accurately by Mr. Simpson or his assistant, and the quantity of water at one point was found to be lessened a few miles further down to the extent of 3,000,000 gallons.

1665. You would therefore place your collecting reservoirs above the points where the stream passes over permeable strata?—No, my object would be to collect the water that comes out by springs from the pervious strata at their junction with the impervious.

1666. Would each tributary have its separate reservoir, or should you have one common reservoir lower down in the neighbourhood of Lechlade?—I propose at present to have one reservoir for each tributary, but if it were cheaper to connect the tributaries than to have one reservoir for each tributary, that would be the better plan to adopt.

1667. Would you have in this district between Cirencester and Banbury a series of reservoirs near the head of the tributaries?—No, not near the head of the tributaries; it would be so far down each tributary as would correspond with the junction of the porous with the non-porous strata, as nearly as possible conformably with the line of outcrop which is marked on the map. Of course in carrying it into practice that line would not be strictly followed, but that serves to put the matter before you.

1668. That line of outcrop would represent a line some feet above the reservoir at Lechlade would it not?—It would be several feet above the junction at Lechlade.

1669. The ground would be higher also, I suppose?—Yes; the plan that would be carried out if this scheme were adopted would be this, that one or two mills as near as possible to the line of this outcrop on each of those streams would be purchased and the mill head would become, in point of fact, a reservoir from whence to take the water, and just below that mill head you would have your compensating reservoir.

1670. Can you give us some idea of the height above the Thames at London of the ground at the lines of junction?—It varies.

1671. You give us a height of 210 feet at Lechlade, this line is apparently above that height, is it not?—Here is a map (*producing the same*) which will make the matter much more clear. It is the geological map of the district, by which you will observe that the various tributaries which come down from the oolite run over the Oxford clay and join the main river in the Oxford clay (*describing the map to the Commissioners*). The line along just below Cirencester to Fairford, Witney, and Woodstock, and from thence to Bicester, marks the outcrop of the Oxford clay where it joins the porous oolite. I have been asked what fall there is from that line down to the main river, and I am afraid I cannot answer that question, but you will observe Lechlade on the map and two mills (*pointing out the same*), the last of which must be several feet above the river, and to that extent only can I answer the question.

1672. Still that would not take it beyond the limit of 250 feet?—No, it would not take it above 250 feet, and the distance being so considerable you could not look to any very great advantage by bringing the water by a contour line to the highest point at which it would fall by gravitation.

1673. All those springs above Lechlade arise in the oolites, do they not?—Yes.

1674. Have you had any analysis made of those waters?—No, I know pretty nearly that they show an extent of hardness of something like 13 or 14 points.

1675. They are waters which are rather harder probably than the waters of the chalk districts?—I think they assimilate very nearly. I should like very much to put before the Commissioners this section (*producing the same*) which shows what I am proposing to do on the river Lea. The point C represents Feilde's weir, which is 80 feet 3 inches above Trinity datum. All the water above that I propose to maintain clear by the interception of the sewage and lifting it in certain places, such as Luton and Bishop's Stortford, where I propose to lift the sewage on to the hills and let it pass through the soil before it reaches the river.

1676. (*Chairman.*) That is to say, you propose to compel the towns to lift the sewage?—Exactly so. They will in any case be compelled; in a few years it must be done. I will assume that by the exercise of compulsion to the extent which I have spoken of, certain towns should lift the sewage, and in other cases that they should discharge it by gravitation and run it over the land, and only discharge the refuse liquid after the service of irrigation into the river below Feilde's weir. By that means the water above Feilde's weir would be maintained in purity, and

B. Denton, Esq.

7 March 1867.

above that point the two water companies, the East London and the New River Companies, would take their supply. You will observe on this section that the water from above Feilde's weir may be conducted into a reservoir so far down the river as to allow of a depth of 20 feet. It is proposed there to collect 20,000,000 gallons per day, for 182 days and from thence to take it by a covered channel to London.

1677. What is the quantity which is proposed to be taken?—The East London and New River Company now draw 40,000,000 daily from the Lea, but the quantity of water stored in this reservoir is compensation for that which may be taken out above to the extent of 20,000,000 gallons per day for 182 days.

1678. (*Sir J. Thwaites.*) The sewage at Luton goes into the river Lea there, does it not?—Yes. Above Fielde's weir I propose that the sewage should be perfectly intercepted and applied on the hills by lifting or in the valleys by gravitation, so that by perfect purification the water may be taken for the supply of the east of London. Below that point all the sewage should be clarified by irrigation or by other chemical processes, and returned into the river, not for the purposes of drinking, but for the purposes of maintaining the navigation and supplying the mills below the point of abstraction.

1679. (*Col. Harness.*) Have you computed the extent of intercepting drains for sewage that you will have to construct for the whole of your scheme?—I am not proposing that any part of this mode of supplying London should deal with the question of intercepting the sewage. I consider that the towns themselves are already under obligation to intercept their own sewage; at any rate in two years from this time they will be compelled to do so.

1680. Would that be only as far as the main stream is concerned?—That only applies to the main stream.

1681. But you are taking the water from the tributaries, and therefore you must intercept the sewage running into the tributaries?—I believe there is a bill now before Parliament to extend the Conservancy of the Thames to its tributaries, and I assume that the powers which are now vested in the Conservancy Board for the main stream will be extended to the tributaries.

1682. (*Chairman.*) By whom is that bill promoted?—By the Government, I believe.

1683. Is there any other point in connexion with your scheme that you wish to put before the Commission?—I want particularly to impress upon the Commission this consideration, that in taking water from a distance, from one valley and applying it to another (take the Thames valley for instance), the onus of proving that the valley to be supplied is incapable of furnishing its own supply should rest with those who would supply it from a distance. I contend most positively that if the matter be fully examined the quantity of water within the Thames basin is more than ample to supply the requirements of the inhabitants. I admit that in point of hardness the water obtained from the primitive formations or from the transition formations of Wales and Cumberland is very superior, but upon the question of quantity there can be no doubt that the capabilities of the Thames basin are equal to any demand; and the point that I wish to speak of now is this, that the increase of population in the north in the manufacturing districts is so enormous that we ought not very hastily to bring water from the heights which surround those districts to another valley which is able to find its own supply. The increase of population in those manufacturing districts is enormous, and must in the course of a few years render the population of the Thames basin of very secondary importance.

1684. (*Sir J. Thwaites.*) Is it not rather a question of free trade, whether you have not a right to go to the best market for the article that you require unless you are robbing other towns?—I contend that you would most seriously rob other towns, besides disregarding existing interests.

1685. Take higher points, such as Wales or the lake district, which it is not at all probable will ever be occupied by a large population, must not these necessarily be gathering grounds for the supply of districts that may be insufficiently supplied, unless you can show that you are robbing other districts and taking water which is due to them?—I believe I can show that most perfectly. The population of the manufacturing districts at this time, taking the counties of Warwick, Worcester, Stafford, Chester, the West Riding of Yorkshire and Lancashire, is 6,000,000. The increase during the last 50 years in Lancashire has been threefold; it has increased from 800,000 to 2,400,000 and more, and taking the increase of the other counties one cannot suppose that the increase of that population would be less than double in 50 years. I am content to take 50 years, and 50 years is but a very small period for us to be assuming when considering the question of water supply.

1686. Supposing the population should be doubled, with your knowledge as a civil engineer, your attention being directed to these questions, are you not of opinion that the gathering ground either in Wales or in the lake district is sufficient for five times the population of that district?—I have very grave doubts upon that point, and doubts arising from a consideration of the subject, and an intimate knowledge of Wales, from having considerable works there. I believe most seriously that it is much easier for us to conserve in the Thames basin a small proportion of the rain collected from a larger area than it can be safe to rely upon a larger proportion of rainfall from a limited area.

1687. Would not it be competent to any one of those towns to obtain a supply of water from ground similarly dealt with in its surface to that which you propose here, namely, the cultivated districts in the upper part of the Thames basin, the high grounds in Derbyshire, and other places which are partially cultivated?—They would not have capacity; there is not the means at command. The whole population is requiring a supply, and Derbyshire is requiring it as well as the manufacturing district which outskirts that county.

1688. Why has not the metropolis, finding its need of a certain article, and that a pure article, a right to go to the very best place at which it can be supplied with that article?—For two very good reasons. The first is, that to take, as is proposed, a large body of water varying from 200,000,000 to 300,000,000 gallons per diem from a river like the Severn is likely so to alter the physical condition of the river itself, as to be very detrimental to it; but allowing that it must ultimately be taken for the manufacturing districts if it does not come to London, it is certainly very much better to apply that water to the use of the districts watered by the Severn, that is to say, to those districts which exist upon the new red sandstone, than to bring that water across the new red sandstone and away from those districts to the metropolis, as it is proposed to do. By retaining the water within the water-shed of the river, as it might be, and by applying that water to the manufacturing districts, which some day or other will require it, the river does not lose the water, but the water still remains, although polluted, for all the river purposes for which it is wanted; whereas if it is taken away from the river to London, the advantage of having that quantity of water in the river is lost.

1689. Would not the same reasoning apply to your scheme, that it would abstract a very large quantity of water from the Thames which you propose to compensate by means of reservoirs storing the rain-water?—I do not propose to take water out of the Thames basin.

1690. You propose to abstract it from the tributaries of the Thames, which is the same thing, and if the law of compensation were put in force either in Wales or in Westmoreland, surely the same result would follow; you would not damage the rivers there more than you would damage them here?—No, but the rivers are differently circumstanced. I believe that the Severn and all rivers rising in high grounds and flowing through the red sandstones, old and new, require a

larger quantity of water for flushing, and that floods are necessary to keep the channels of the river open. Over these formations the rivers pass by comparatively low gradients seaward, bringing down turbid waters from their sources. The surface beds of the old and new red sandstone are easily abrased, and if there be not frequently full bodies of water to scour their courses of detritus and river-side abrasions, they would soon become choked, and navigation would suffer. I have particularly observed this influence in North and South Italy, where the rivers from the Alps and Apennines pass over comparatively flat districts before reaching the sea. The fall of the Severn from the English stones near Kingroad, is 34 feet in 40½ miles, while from Gloucester to Worcester it is only 16 feet in 29 miles, and from Worcester to Stourport 17 feet in 12 miles. These observations do not apply in the same way to the Thames; but that is not the paramount point to which I should draw the attention of the Commission; it is to the requirements of the manufacturing districts for an increased supply. For instance, if the increase of population as I say will be in 50 years at least double, and instead of 6,000,000 there be 12,000,000, you would require at least that which is proposed to be brought to London from either Wales or Cumberland to supply the additional 6,000,000 of population which will be within the manufacturing districts.

1691. (*Sir B. Phillips.*) If I understand you rightly, you say that the Thames basin will supply a quantity sufficient for the purposes of London?—Yes, quite sufficient.

1692. But as to quality, I do not think that you express a strong opinion, or rather you say that the quality is not so good?—I say that the quality for drinking purposes is equally good, and that all the most healthy towns in England, and, in fact, throughout Europe, have hard water from calcareous strata. There are purposes which have been referred to by Professor Way to-day, for which the water of the Thames would not be so good, but with the power which we have of softening water by Clarke's process and by the power of chemistry, I assume that it is certainly easier to make hard water soft than to purify water, and by having recourse to Clarke's process or to any other process that objection might be overcome.

1693. A great element in the supply of water to the people of London would be the sanitary consideration; do you suppose that looking at it in that point of view the water supplied by the Thames basin would be quite as good for sanitary purposes as the water supplied to the lakes of Westmoreland and Cumberland?—I do not know any reason why it should not, the only disadvantage in the Thames water is its hardness, and that may be reduced, for we know very little indeed of what the effect of collecting water in large reservoirs will be. A little circumstance came before me, or rather was mentioned to me by Mr. Beardmore the other day with regard to a spring rising from the chalk which flows down by a watercourse into the Lea. It is part of his duty as engineer to the River Lea Commissioners to keep this watercourse clear; he has to empty it periodically of any sediment or any matter that may be in it, and he told me that the quantity of lime which was precipitated by the water in its passage from the spring where it rises to the Lea was very great indeed, and in fact that the matter which he had to remove from the watercourse consisted of lime which could only have been precipitated by the water in its transit from its source to the Lea. And I submit that we are not now in a condition to judge of what would be the softening effect of the collection of a large body of water in reservoirs as I am proposing it should be collected.

1694. Reverting to the sanitary uses of water, are you aware that during the rage of the cholera in the eastern parts of London last year, there were many eminent men who gave it as a positive opinion that in many of those districts the virulence of the disease was materially influenced by the bad character of the water which was supplied to the inhabitants?—I know that to be the case, but I know that the cause was the pollution of the stream, not the hardness of the water. I am assuming as the very basis of the project which I am laying before the Commission that the conservators do their duty, and pollution is prevented, that no water is taken from the streams until the sewage has been perfectly intercepted above the point of abstraction, and that below the point of abstraction (with which, in the present inquiry, we have nothing to do,) the law will insist upon the sewage being so dealt with that it shall no longer be an objection to sight or nose; but in dealing with the matter of water supply for drinking, no water should be taken where any pollution of any sort can enter. I am assuming also that as the loss of water in the Thames as it passes through the metropolis is an evil almost as great, if it be not quite so, as the tainting of the water with sewage, the companies will be bound to store water in winter for compensation in summer, and I am further assuming that the public insist upon having a constant supply at high pressure at the hands of the existing companies, so as to place their supply upon an equality with that proposed to be brought from Wales or Cumberland in that respect.

1695. Are we to understand that if the water, which is at present in a state of pollution, has that pollution removed, then for the sanitary uses of London it would be as good and as healthy as the water taken from any other source?—Exactly so, there can be no doubt about it.

1696. (*Sir J. Thwaites.*) Subject always to the question of the degree of hardness?—Yes, always assuming that.

1697. (*Mr. Prestwich.*) You collect your waters from very different geological areas, and I think you stated that above Lechlade you have made no experiments with regard to the quality of the waters. Have you made any experiments with regard to the quality of the water in any of the other districts?—No, I have assumed that there might be a trifling difference between the waters derived from the chalk, and the waters derived from the oolite; but the difference must be very slight, and, generally speaking, it is represented by a degree of hardness of from 13 to 14 degrees.

1698. The experiments upon waters from the chalk show that they generally vary in hardness from 12 to 19 degrees, whereas waters from the lower oolites vary from 16 to 25 degrees; therefore it is probable, is it not, that the waters from the oolites would be generally harder than those from the chalk?—Yes.

1699. Is there not this further fact always to be observed, that when those hard waters flow in long channels of a certain distance, they always lose a portion of their lime, and become reduced to one uniform level of 12 to 16 degrees?—Yes.

1700. Therefore you would anticipate that the waters from the whole of this district would reach London at a moderate degree of hardness?—Yes, 13 or 14 degrees, which might be reduced if the view which I have advanced is true, that by collecting water in large reservoirs a certain amount of precipitation would take place, which would reduce that hardness; and that it might be further artificially reduced by recourse to chemical science.

1701. (*Sir J. Thwaites.*) What is Clarke's process for reducing hardness?—The introduction of quicklime.

1702. (*Mr. Prestwich.*) Have you paid attention to the springs in the valley of the Kennet?—Not particularly; I have not gauged them.

1703. Do you propose to collect water from the valley of the Kennet?—Yes.

1704. And from the valley of the Wey?—If required. I believe that the whole of the tributaries of the Thames may be laid under contribution.

1705. In the valley of the Wey you get waters of a much softer quality, do you not?—Yes, they rise from the greensand, I believe.

1706. And those waters have been found to contain but a very small quantity of carbonate of lime?—Yes.

The witness withdrew.

Adjourned to Wednesday next, at 11 o'clock.

Wednesday, 13th March 1867.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND, K.G., IN THE CHAIR.

Sir JOHN THWAITES.
Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

Professor A. C. RAMSAY, LL.D., F.R.S., examined.

Professor A. C. Ramsay, LL.D., F.R.S.

13 March 1867.

1707. I believe you are at the head of the Geological Survey department?—I am director of the Geological Survey of Great Britain under Sir Roderick Murchison, who is the director-general of the whole establishment, and I am Professor of Geology at the Royal School of Mines in Jermyn Street.

1708. Therefore you are well acquainted with the geology of Great Britain?—I am with the greater portion of it; with all that has been surveyed by the Geological Survey.

1709. And are you conversant with the district in Wales from whence Mr. Bateman proposes to bring water to the metropolis?—Yes, I know it exceedingly well; I surveyed the greater part of it myself geologically, and I have brought the geological maps here, which the Commission can see if they require to do so. The sources of the Severn are on the flanks of Plynlimmon, and I know the country well, and the nature of its geology.

1710. From your knowledge of the character of the country would you say that the water to be obtained from that district would be of a good character?—Yes; I should say that it would be soft. The rocks consist of slaty rocks, and grits and hardened sandstones, but chiefly of slaty rocks; and over the greater part of that area they are unfossiliferous, and contain little or no carbonate of lime.

1711. The waters are what are termed soft waters?—Yes.

1712. What is the character of the country; is it covered with heather?—I think there is a good deal of heather, but also a great deal of upland grass land. On Plynlimmon itself, for example, there is a great deal of grassy land where cattle are pastured.

1713. Is there much peat in that district?—My recollection is not sufficiently definite to say whether the ground is covered with much peat. There are in reality only two large peat mosses that I know of in Wales, and they are not mountain mosses, but in the plains. One is between Machynlleth and the sea on the banks of the river Dyfi, and the other is on the Teify in Cardiganshire, near Tregaron. The country, as a general rule, is not what I would call peaty.

1714. Those two large mosses that you speak of would not come within the district whence Mr. Bateman proposes to take water?—No; they are quite unconnected with it. The water that runs through them drains in opposite directions to the sources of the Severn altogether.

1715. If there is any peat in that district it is so small a quantity that it would not, you think, have any bad effect upon the water?—I have no doubt that the water would contain a little vegetable matter from the peat, because no hilly country of this kind is destitute of peat altogether, and a small quantity of peat here and there will serve to give a tinge to the water.

1716. Heather would grow upon the peat, would it not?—Heather grows upon peat, but not invariably or only there. Heather will also grow in a common soil. There are some peaty tracts, although I cannot remember precisely where they are, but it is not a peaty country in the sense in which Ireland is a peaty country, or that the Western Highlands is a peaty country, or that certain parts of Galloway are peaty.

1717. (*Mr. Prestwich.*) Have you noticed whether the streams are much discoloured by peat at any particular seasons of the year?—I have not noticed that, but my impression is that they are clear as a general rule, and that the water is exceedingly pleasant to drink. I drank a great deal of it in marching all over the ground in summer, and that is the impression which has been left upon my mind; but it is a good many years since I was there.

1718. (*Chairman.*) When you were surveying that country did you take any notice of the rainfall?—No, excepting that there is a great deal of rainfall; but I did not test it in any way. I made no observations upon that point.

1719. (*Mr. Prestwich.*) The analysis of the water shows the presence of a certain proportion and rather a large proportion of organic matter, which arises, does it not, in great part from peat and heather?—Yes.

1720. That analysis was made in the month of May, but the question is, whether in the fall of the year, in the late autumn, the quantity of vegetable matter would not be larger in those streams? Have you noticed at that time of the year that the rivers were discoloured from that cause?—No, I have not noticed that.

1721. Can you say whether this country is much wooded?—Very little; it is chiefly a high, unwooded country.

1722. (*Chairman.*) Is this district somewhat like Dumfriesshire?—It is very like Dumfriesshire, only that a great deal of it is rather higher; the ground on Plynlimmon rises up to 2463 feet, and a great deal of the country is 1,500, 1,600, and 1,700 feet high.

1723. (*Mr. Prestwich.*) Is there any great thickness of soil in the valleys?—There is a quantity of thick alluvial soil in the lower valleys. From Llanidloes down towards the Severn and the Tarannon rivers there is a good deal of alluvium.

1724. Do you see on the map the valleys where it is proposed to construct the reservoirs, which are marked in red?—Yes, there are three. There is one at Llanidloes, and there is a great deal of alluvium in that valley. That is on the river Tarannon, which joins the Ceryst. The whole of that valley where the reservoir lies, or nearly the whole, contains, I believe, a quantity of gravelly alluvium.

1725. Not silt?—I cannot answer positively, but I think there are sure to be silty alluvial beds on and mingled with the gravels.

1726. How is it with respect to the other three reservoirs?—There is alluvium in those valleys also, that is to say, in the valley of the Garthbibio, and Cann-office on the river Banw.

1727. (*Mr. Harrison.*) Would that be at the level shown upon Mr. Bateman's plan, or lower down the stream?—Where the reservoirs are marked upon this plan.

1728. (*Mr. Prestwich.*) Is the alluvium of a character, as you sometimes see in mountain districts, to form rich meadows and fertile soil?—Yes, grassy meadows; but as far as I recollect, though I am not quite sure about it, the substratum is chiefly gravelly.

1729. Do you think that the alluvium is of such a character that, supposing the valleys to be dammed up, and reservoirs formed upon their sites, it would act injuriously upon the water so collected?—No, I should think not. That is not the case in any of the reservoirs that I know of in other parts of the country for the supply of Liverpool and Manchester, and so on, in the Millstone-grit country, where I think there is sometimes a small stratum of peat, and it does not seem to injuriously affect the water. There is

another reservoir which is near Llanwddyn, and there is a covering of alluvium over the valley where the reservoir is drawn on the map. The name of the river is the Fyrnwy.

1730. (*Chairman.*) Are there any mines in that district?—There are no mines of importance in that district, or there were none such when I surveyed it.

1731. (*Sir J. Thwaites.*) When you say that district, do you mean the whole district from which Mr. Bateman proposes to take water?—Yes, when I was there there were no mines in that district of great importance.

1732. How long is that ago?—It is from 15 to 20 years ago since I surveyed this country. The chief mines of Cardiganshire lie on the opposite watersheds south and west of Plynlimmon. There are some in this district, but they were not of any serious importance. They may be of importance now, but they were not when I was there.

1733. (*Chairman.*) What mines were they?—They were, I think, all of them lead mines.

1734. Do you know at all how near the proposed reservoirs those mines which you are now speaking of are situated?—Whether they are in operation or not I do not know. There are some mines on the mountains to the west of Llanidloes, and the rivers of that country drain down into the Severn and into the Ceryst and the Tarannon. The rivers run through the country in which the mines are situated, and they drain into those rivers where the reservoir is proposed to be built. Further north in the other valley, the valley of the river Banw, there are no mines, or there were none when I was there, and I do not believe there are any now. It is not the kind of rock which experience shows contains ores of metals in that country. As to the third, at Llanwddyn, there used to be some small mines in that neighbourhood, but none of importance, and the rivers that drain into the valley of the Banw near Llanwddyn do not run through a mineral district.

1735. (*Mr. Prestwich.*) Have you the mineral veins marked upon this map so far as they were known?—Yes, so far as they were known at the time of the survey.

1736. Are there any ferruginous beds, or any likely to give rise to mineral springs and affect the water?—No, not to my knowledge. The rocks are not ferruginous any more than that any slaty or shaley rock always contains a little colouring matter, and a small proportion of iron.

1737. Do you know of the existence of any mineral springs within that district?—I know of no mineral springs within the district.

1738. (*Mr. Harrison.*) Will you refer to that plan which is before you, and follow up the river here called Afon Dyfi to the summit, taking the district between the watershed to the eastward, and the watershed to the west of the mountain of Dinas Mowddwy, and then draining into Afon Dyfi, what is the general character of the rocks?—The rocks that form the mountain range on the west, namely, the Aran Benllyn and Aran Mowddwy range, consist of feldspathic porphyries chiefly, and beds of Silurian volcanic ashes; and east of them, and lying on them, are a series of dark blue or black slates; then a little further east there is a thin strip of impure limestone, say 20 feet thick, known as the Bala limestone, but it is so small in extent that it does not seriously affect the waters of the country in any way; above that limestone there are more slaty beds, with a few thin beds of grit. The general character, therefore, of the country to the west of the river, is slaty, with thin beds of grit, and masses of felds pathic porphyries, on the extreme west, which always yield very pure water—the porphyries invariably do. Near the east of the river there are other slaty beds of the upper Silurian series. Those on the west of it belong to the lower Silurian series; and the water from the rocks of the upper Silurian series here will not, in any essential particular, as far as the rocks are concerned, differ from that which flows over the beds of the lower Silurian series.

1739. Is there any portion of the district which would be within that watershed containing beds of minerals at all likely to be worked in any way in those slates?—No; further north they have found some phosphatic minerals associated with this limestone, but I have never heard that they have been found in the valley of the Dyfi; and further north the quantity is so small, and the area is so limited, that it would not, in my opinion, in any way affect the quality of a large supply of water.

1740. Taking generally the watershed of that river, it would appear to afford over a large extent a stratification likely to yield the purest soft water, and water not liable to pollution by any working of mines?—It would not be polluted in the present state of mining in the country. That river drains in an opposite direction to that of the sources of the Severn.

1741. (*Mr. Prestwich.*) I presume that the country further to the south is a district in which it would be likely that trials would be made from time to time for minerals?—I know no reason why they should not, excepting that generally in the neighbourhood of these streams they have not been very profitable, as far as I know.

1742. Therefore, although they may show well at first, they would not be likely to lead to a large result?—Probably not. Mr. Warrington Smyth could answer such a question as that better than I can.

1743. (*Mr. Harrison.*) If you go further north to the watershed falling toward Bala Lake, would not the stratification be as nearly as possible similar to the watershed falling to the south-west?—As you go up to Bala Lake the rocks are of the same geological age as those which I have described; but there is this difference, that they become much more fossiliferous and full of Silurian shells, and therefore the waters which come out of those rocks would be more calcareous; still, these waters would not be so hard as to be what you would call hard water.

1744. From the analysis of the waters taken from Bala Lake, they appear to contain only about two degrees of hardness?—Yes, that is so; and the reason of that is, that the larger portion of the waters which run into Bala Lake come from the west and south-west of the lake, from the range of the Arenigs and Craig Aderyn. The rocks there consist of feldspathic porphyries, and the black slates that lie upon them directly are unfossiliferous or sparingly fossiliferous. East of Bala Lake the rocks become much more fossiliferous, and the water there I should expect to be harder than the water which flows in on the west of the lake. On the west of the lake, as far as I recollect, there is a considerable quantity of peaty ground in the lower part of the territory.

1745. (*Mr. Prestwich.*) Should you consider the Bala Lake district to be more peaty than the district which it is proposed to drain, and where the reservoirs are to be situated, or do you consider the surface vegetation of the Bala Lake district to be similar to that of the district proposed by Mr. Bateman?—Up among the mountains of the Arenigs the vegetation would be much the same, but round about the lake there is a very considerable amount of cultivation, and that would make a difference, or might make a difference.

1746. Is there more cultivation there than there is in the districts in which the reservoirs are proposed to be situated?—I think not much more than where the reservoirs are situated. There may be more than in the case of the upper reservoirs perhaps, and I think there is more cultivation in the parts of the country through which the water flows that runs into the lake than there is in those parts of the country through which the water flows to get into those reservoirs, supposing they were constructed. The lake country is, to a great extent, a lower country.

1747. (*Mr. Harrison.*) There is another large

Professor A. C. Ramsay, LL.D., F.R.S.

13 March 1867.

watershed, is there not, draining into the Twrch river?—Yes.

1748. What do you consider the general geological features of that district to be?—The greater portion of it consists of lower Silurian rocks, chiefly of a slaty character, interbedded with long lines of feldspathic porphyry, which is an igneous rock, and feldspathic Silurian ashes, of lower Silurian age; and on the flanks of the country there are the upper Silurian rocks which I spoke of before. The quality of the waters of that country so far as the rocks are concerned would, in the main, be similar to the quality of the water about Plynlimmon, or in the country south of Bala Lake.

1749. (*Mr. Prestwich.*) It is proposed to place these reservoirs at a height of about 500 feet above the sea level. Can you say whether the rocks there are in any way fissured or shattered in such a manner as to allow of the escape of water to the lower level through the sides of the hills, or the bottom of the reservoirs?—I should certainly not expect it—it is the last thing that I should expect.

1750. Are there any permeable beds at or above the 500-feet level by which some portion of the water might escape and be delivered to a lower level in the form of springs?—None that I know of.

1751. Is there any mass of permeable strata above the 500-feet level such as would absorb a portion of the rainfall and store it for subsequent and gradual delivery in the form of springs above the level of 500 feet?—There are porous rocks—the grits especially are more or less porous, and will absorb waters; and under favourable circumstances, which I am not prepared to say that I can point out at the present moment, there might rise to the surface waters in the form of springs, but the mass of the country consists of a rock which is not easily permeable by water. It is true that slaty rock is not easily permeable by water, though it does go through the joints and fissures such as they are; yet, as far as my experience goes, in the main, slaty rocks are singularly dry when you get into them.

1752. Is the country tolerably free from springs?—I am not prepared to say so or to deny it.

1753. Do you know of any porous strata there such as the oolites for example?—There is nothing of the kind.

1754. Then you would consider that the rainfall, except such as would be lost by evaporation and taken up by vegetation, would be all carried off by the streams and rivers?—The larger part of it.

1755. Would you consider that the delivery of the water follows soon upon the rainfall?—Yes, I should consider so from the nature of the country, but I have not made actual observations on that point.

1756. Should you consider, therefore, that the water delivery from such a district would vary very much from season to season?—Yes.

1757. Would it not be entirely dependent upon the actual rainfall of the season in each year?—Yes, it would be dependent upon the amount of the rainfall of the season; my experience shows that it is generally large, it is a very wet country.

1758. And very variable?—Of course it is variable, but there are many fine days and sometimes fine weeks and even months.

1759. In long continued droughts should you consider that the water supply would be dependent upon that which had been previously artificially collected in lakes or reservoirs?—I never knew a river run dry in that country.

1760. You have stated, I think, that the quantity of absorbing strata is small, and that therefore the springs are but small in their area?—Yes, as far as I recollect. It is not a country for springs like some countries that we know.

1761. I think you stated that the greater part of the surface was a hard rock surface?—It is a slaty rock surface, it is not the kind of surface into which a great quantity of water would percolate as a general rule; and the larger part drains off the country into the rivers, but the quantity of rain which falls throughout the year, although I do not know what it is, is so great that in the large rivers there is generally plenty of water.

1762. Are you speaking of where you get into the lower part of the country or above the level of 500 feet?—I should think that above the level of 500 feet by a good deal there is plenty of water.

1763. Should you consider it safe in a district like that, where you say there is but a small amount of rock which could absorb water and deliver it afterwards, to depend upon anything beyond the fall of rain from year to year?—If enough rain does not fall to keep the rivers running, and if you depend upon springs, I should say that it is a very bad thing to be dependent upon under those circumstances. But as I said before I have never seen the rivers with any lack of water in them. I stayed years in Wales backwards and forwards and water is the characteristic of it, but I cannot answer the question which you have put, namely, whether if there were no rain to fall for six months or some such period as that there would be a sufficient quantity of springs to keep the reservoirs full. I have no information upon that subject.

1764. My question was not intended to convey that, but you say, do you not, that the surface is composed essentially of hard slaty rocks?—Essentially so.

1765. And that there is nothing to absorb water and store water and give it out by slow degrees?—If so it is exceptional. All slaty rocks are apt to be decomposed for a good many feet below the surface, and they would be permeable by water to that depth.

1766. But they are not capable of storing water like the oolitic or cretaceous strata?—No, not to store it like those strata.

1767. Therefore, in a district like that, you could not in a year of small rainfall look to any previous subterranean storage of water to increase the minimum rainfall of that year?—I should think not in any serious degree.

1768. In estimating the quantity to be delivered you must base your quantity, must you not, rather upon the minimum rainfall?—You must place your dependence upon what flows off the surface in any particular year or part of the year.

1769. (*Mr. Harrison.*) You did not make any observations, did you, on the rainfall when you were in that part of the country?—No, no precise observations.

1770. (*Mr. Prestwich.*) It is a very rainy district you say?—Yes, it is a rainy district, all Wales is.

1771. (*Mr. Harrison.*) Taking the geological features of this particular district which you have been describing, do you think that it is as favourable as any other geological strata in England for the supply of soft water, or could you point to any particular district that would yield a purer water?—No, I do not know any district in England that would yield a purer water. The water of the Silurian rocks in any part of England or Wales is very much the same. The general structure of this country strongly resembles part of Westmoreland and Cumberland, the rocks are of the same age and their lithological character is tolerably similar.

1772. (*Chairman.*) Are you acquainted with that part of the country which we call the lake district?—Not at all so intimately as I am with Wales. We have just begun to survey it, and therefore I do not know so much about it.

1773. If you look at the map before you containing the district of Ullswater you will observe the part coloured blue and the part coloured pink just below it, in which are situated Ullswater, Thirlmere, and Haweswater; do you imagine from the character of the country that the water would be good for the purposes of the metropolis?—I have never been in that country, but it is quite notorious what the nature of the rocks is—I know what to expect if I were to go there, and I should find what I expect—and the water

ought to be in a general way as far as the rocks are concerned of the same quality as that in Wales.

1774. Geologically speaking, would you imagine that the water which could be obtained in that district would be as good as the water that you would find in Wales?—I would expect the water to be the same as nearly as may be.

1775. You think that there is no reason geologically why it should not be?—The general character of the country is the same, it is formed of the lower Silurian rocks. Part of the area coloured blue on the east, as far as I can make out by a comparison of the maps, consists of limestone, but I have not surveyed the country and do not speak from personal knowledge. Further south and south-east I know the country, but not where it is coloured blue on the map.

1776. Are you aware whether there are any mineral formations in that district?—I am not aware. In the part that I know there are some iron mines, but that is further south, and quite out of the district.

1777. (*Mr. Prestwich.*) It frequently happens, does it not, that under the alluvial soil of a valley there is a considerable accumulation of gravel following the course of the valley?—Yes.

1778. With regard to the sites of Mr. Bateman's reservoirs in Wales, where the dams are proposed to be placed, should you consider that the gravel underneath the alluvial soil in those spots would be of such a thickness as to interfere with the construction of the proposed works, or does the rock at that point come near to the surface?—I do not recollect.

1779. You have walked over the greater part of the Welsh district, are there many villages or hamlets there?—No. In the upper grounds where the water gathers there are very few. It is a high pastoral country for the most part, with a few scattered farmhouses; there are no villages of any importance until you get into the great main valleys where the larger rivers run.

1780. Down at the points where the dams are proposed to be constructed are these villages or collections?—There are no large villages or collections of houses except the town of Llanidloes itself, which is a good sized town, but as a general rule the villages are exceedingly small. Trefeglwys, for example, is a very small village.

1781. Is there much of the land under cultivation?—A great deal of the land is under cultivation on the flanks of the great main valleys.

The witness withdrew.

The Reverend James Charles Clutterbuck examined.

1782. (*Sir J. Thwaites.*) You are a clergyman, and you have given considerable attention, have you not, to the supply of water to large towns?—Yes, I have.

1783. And to London in particular?—Yes.

1784. You are fully acquainted with the watershed of the Thames?—Yes, I am.

1785. Can you inform the Committee as to the geological character of that watershed, and how it may affect the water which ultimately flows into the Thames?—The watershed of the Thames, commencing with the lower part, which is the upper geological series, begins with the London and plastic clays and the chalk formation, including the upper greensand and the gault. Beneath that is the lower greensand and the oolitic strata down to the Lias clays. The great source of water supply to the Thames is decidedly the chalk proper, the upper and the lower chalk, and especially we may say the upper chalk. There is a source of water to the Thames in the upper greensand. The gault is a retentive stratum, and being clay of course is not a water-bearing stratum; and beneath that there are traces or patches, as we may call them, of the lower greensand. Then there is the Kimmeridge clay, which is a retentive stratum, and therefore yields no water, and below the Kimmeridge clay you have the oolite. The Portland oolite is distributed here and there above the Kimmeridge clay. Below the Kimmeridge clay we find the coralline oolite, which is also a source of water supply to the Thames. Below that is the Oxford clay; and again below that, cropping out in the Cotswold hills, are the larger oolites, and the lias formation, consisting of the upper lias clay, which is a retentive stratum, and the marlstone, which yields a certain quantity of water, and the great body of the lower lias clay, which upholds the whole of the water in the oolitic strata. That is, I think, a general view of the geological structure of the valley of the Thames.

1786. Do I rightly understand the substance of your answer to be that the largest portion of the water due from the watershed of the Thames basin is from the chalk?—Decidedly; that is a point I wish to make.

1787. Have you turned your attention to the properties of that water as to degrees of hardness?—The degrees of hardness in chalk water are very well known; they are known to be from 17 to 20 degrees of hardness. I think that is the scale which is generally given. It is known to be a hard water, such as is supplied to London from the Lea. I think that would be one of the best types of the chalk water; however, that comes out in analysis; it would be a type of the water from the chalk. I am not a chemist, and therefore I do not attempt to speak with certainty upon that point.

1788. (*Mr. Prestwich.*) By the Lea do you mean the New River water?—Yes; the water supplied by the New River Company.

1789. Such as was originally delivered in London by the New River Company?—Yes. I will confine myself to that, and say that that is a type of the chalk water; you will find it a hard water.

1790. (*Sir J. Thwaites.*) When we speak of a geological basin and its yielding power, that would be somewhat dependent, would it not, upon the fact as to whether that basin has been tapped by artesian wells or otherwise?—Decidedly it would.

1791. If there is a drain upon a basin by means of artesian wells the general yield of that area would be lessened?—Decidedly.

1792. What is the condition of the watershed connected with the Thames in that respect?—All the district in London and round about London has been tapped by artesian wells, and there is a depression under our feet of, it may be, 60 feet below Trinity high-water mark. I think that has been established. I read a paper at the Institute of Civil Engineers in 1850, of which I have a copy here, showing that has been the depression in consequence of the pumping of the different establishments in London.

1793. From what has it been depressed?—As far as I can gather from the facts which have come under my knowledge, and I have had access to a great many, the state of the case appears to be this, that originally, previously to any tapping by artesian wells, the level to which the water was regulated was Trinity high-water mark, as near as may be, or perhaps the mean level of the Thames where the sand outcrops in the Thames, which is about Deptford. As far as I have been able to gather from the way in which the establishments in London—the great breweries and distilleries and other places—have tapped the water in the chalk, the depression is in round numbers 60 feet below Trinity high-water mark. The Commissioners will find very much information upon that subject in a book of Mr. R. W. Mylne, in which he has published subterranean sections of the London basin, which are exceedingly valuable, and, I believe, may be thoroughly relied upon. As I have said, the depression is 60 feet below Trinity high-water mark, running up at

Rev. J. C. Clutterbuck.

13 March 1867.

an angle into the country, because no subterranean water is flat, it is always lying at an angle; for instance, it will stand above Trinity high-water mark at Cricklewood, and it is depressed 60 feet below Trinity high-water mark in the centre of London.

1794. Have you directed your attention to the power of absorption within this area?—In order to meet what you wish to know, will you allow me to say I do not think that the depression of the level of the water seriously affects the yield; it has not been traced, and I have never been able to trace it to the springs above; it seems to have been confined to the depression, so that those who use artesian wells have merely deprived themselves of water.

1795. I do not think you quite apprehend my point, which is this, that a basin full or a basin empty will seriously affect the amount of water due from a given area?—Yes.

1796. And the absorbing power of the earth would necessarily be greater if you tap the lower part of the basin by means of those artesian wells?—Exactly.

1797. I want to know whether your attention has been directed to the watershed of the Thames, and whether, having regard to its general flat character, the absorption would not be very considerable when you take into account the fact that it is tapped at the different points to which you have referred?—You mean that there would be a loss of water to the basin from that tapping.

1798. Take the case of an ordinary basin of similar geological formation, and of surface equality, not tapped, and a basin of a similar character tapped as the London basin is obviously tapped, would the power of absorbing a large amount of rainfall be greater in the London basin than in a basin that was not so tapped?—I think the power of absorbing an amount of rainfall would not be affected by tapping. I think that the overflow from other parts might be affected, but I think that the water would just in the same way have been absorbed; the difference would be that it would have been delivered out in a different way. It is taken unnaturally, or in an artificial manner, instead of flowing out in a natural way. I do not think that the absorption of the water would make much difference, but the delivery of the river above might be affected by it.

1799. Supposing there were no tapping at all, and the basin were filled up to the surface, saturating every part within a given measurement of the surface of the ground, it is clear that the rainfall could not have been absorbed, except to a very limited extent; but if you are tapping that basin at a lower point, and drawing off the water at the upper point, the absorption must be greater, must it not, as it appears to me, than if it were not tapped?—I think, from the peculiar nature of the chalk, though it might not seem reasonable at first sight, that is not the case. I think there would be the same quantity absorbed. The only difference would be that it would be delivered out in a different way. It would be delivered naturally in its outfall into the river Thames below London if it were left to nature, but if it were abstracted, as it is, it might quicken the delivery from above, and prevent so much water issuing from the streams, but I do not think that the absorption would be affected by it.

1800. Could those lower streams be available for the supply of water to the metropolis?—If you mean the springs under our feet in London, they would be available as far as they go, but they have been taxed already too heavily. The supply has been over-taxed, and the consequence has been that there has been an unnatural depression. The water has been taken quicker than it naturally comes, when it is naturally delivered, and it is drawn down at an unnatural angle.

1801. Do you think that the yielding capacity of the water stored in the London basin has been mastered by the several wells which have been sunk?—Decidedly so as regards the lower part of it.

1802. And that any hope of obtaining a supply of water for the metropolis from that source would be a failure?—Yes, an utter failure.

1803. (*Mr. Prestwich.*) Are you speaking now of the chalk beneath the tertiary strata—beneath the London clay?—I am speaking of chalk beneath the London clay. Here is a section (*producing the same*) upon which I can rely, showing the whole of the line of water, and showing the point at which the waters are depressed. There is no delivery of water above ground further than at this point (*pointing out the same on the section*).

1804. (*Sir J. Thwaites.*) What number of miles is that from the metropolis?—I suppose it must be about 13 or 14 miles from London, but there are places nearer to London, in the direction of Surrey, where the water comes above ground; but the water that supplies the greatest part of the artesian wells in London on this side of the Thames comes from the north, and there is no water delivered above ground, I suppose, within 12 or 14 or 15 miles.

1805. You are well acquainted, are you not, with the surface condition of the watershed of the Thames for some hundred miles up?—Yes, all the way.

1806. Is it highly cultivated?—It is highly cultivated, decidedly.

1807. And what, in your judgment, would be the effect upon the water in the rainfall passing through a soil so cultivated?—With reference to the chalk surface, I do not conceive that there would be any great amount of effect produced by cultivation on the water percolating that part of the country, because it would sink through so very much soil. First of all, according to what is held by Professor Way and others, the soil would entirely deprive it of any of its organic matters, or rather, if it took up a little on the surface, it would be deprived of it before it got far down; at least, I think so.

1808. The filtration would probably deprive it of all matters in mechanical suspension, but would it of all matters in solution?—I will answer that question in this way, judging by the analyses of this water I have seen, there has been scarcely a trace of any organic matter in it.

1809. But that would not apply, of course, to the water which finds its way into the river. It is proposed to intercept and utilize the flow from those rivers of the water which passes off immediately from the land without being filtered through chalk or anything else. What would be the condition of water under such circumstances?—First of all, that has reference to the retentive strata. I think that you have got a map, which is coloured after the same fashion, as in a paper of mine on the Thames which I read at the Institution of Civil Engineers. In that I have only taken the upper part, but this map gives you the whole.

1810. Looking at that general condition of the surface and at its geological formation, is there in your judgment any objection to that gathering area for water for the purposes of domestic use?—No, I think not, I cannot say that I see any. Of course the water would be turbid in many places from flowing off the clays. The first clay which you have to deal with would be the London clay. You are aware that there are a certain number of reservoirs for the supply of the canals; there is one at Elstree, and there used to be one at Ruislip. I think that is done away with, but the former I believe exists still, and there are a certain number of other reservoirs. There is one between Cricklewood and Edgeware.

1811. Those waters have been gathered I presume in the ordinary way?—Yes, they have been gathered in the ordinary way; they come turbid to the reservoirs, but if they were allowed to go through the process that the London waters are by filtration they would part with all or almost all their objectionable properties.

1812. (*Mr. Prestwich.*) You state that there is a great exhaustion of the water in the chalk beneath London, does not that arise from the difficulty of transmission and from the flow of water from the outcrop of the chalk to beneath London being exceeded by the

extent of pumping at the different London wells?—That is exactly the case; it does not come to the place whence it is raised sufficiently quickly to prevent that depression.

1813. Is not that depression extremely local?—Decidedly.

1814. How does it affect the chalk at its outcrop?—I never could trace it to the outcrop. The water rises and flows down the rivers there.

1815. Do you consider the springs in the chalk area to be unaffected by the pumping underneath London?—I think so, at any rate I cannot trace it; I have tried to trace it in vain. I have never been able to trace that the quantity raised in London has any visible effect upon the waters in the outcrop; the waters would naturally flow in a certain quantity here, and they are intercepted before they get to their natural outfall, and they do not come quick enough to maintain the natural level at which they would fall out.

1816. With regard to the absorption in the chalk area, the surface of the chalk above the line of water level would always absorb water irrespective of the delivery by springs or pumping by wells, that is to say, the absorbing action of the chalk surface would always proceed and be unaffected, would it not?—Entirely; the absorption and the delivery are two different things. The absorption would be just as much if there were no bottom to the chalk as if there were; if you could pump all the water out the absorption would not be at all affected by the way in which the water is pumped out from below.

1817. Then the springs in the chalk you consider to be still in their full force?—Decidedly, I think so.

1818. You have described the very variable series of strata which serve to form the drainage area of the Thames valley and its tributaries, taking the whole of the area, have you not?—Yes.

1819. You are aware, of course, that generally on a large scale the delivery by rivers is upon the general average in these latitudes equal to about one-third of the rainfall of the area which the river drains?—One-third, I think, is a liberal allowance.

1820. But that one-third is made up of very different sums in the different strata?—Decidedly.

1821. That is to say, that there would be a larger immediate delivery of rain falling on slate rocks, or on clays, whereas the rain falling on oolitic rocks and chalk would be absorbed for future delivery?—Decidedly.

1822. Can you give us some idea of the extent of the chalk area within the Thames district?—I have not measured it but it is very extensive. I scarcely understand whether the question refers to the upper Thames above the pumping district or whether it includes the New River Company.

1823. My question had reference to the upper Thames?—When I am speaking of the upper Thames I mean everything above the tideway. It extends from beyond St. Alban's to Marlborough in a line. I cannot tell you the area because there are spots which are covered by a retentive stratum of clay, or rather beds of plastic clay here and there dotted about as they are marked upon this map, therefore those do not absorb the water in the way that the chalk does where it is not covered with these retentive strata, so that it would be difficult to reduce it to a measurement, though it might be measured. It is a very large area.

1824. Of several hundred square miles?—700 or 800 I should think. It might be easily estimated, but it is very large. I would take out one-sixth or thereabouts for the retentive strata.

1825. (*Sir J. Thwaites.*) When you speak of the yielding power of any given area having regard to the amount of rainfall upon the area itself and gauging the river or rivers that carry off the net result after allowing for absorption and evaporation, is there not this difficulty, that it is probable that some spring actually within that area, having regard to the geological formation, may yield water due from another gathering area; or to put it in other words, supposing we had an area of 600 square miles, and we were anxious to ascertain first the amount of rainfall upon that area, supposing it were to be 30 inches, and to ascertain the net result after allowing for absorption and evaporation and so on, in order to get at that result you would have to gauge the rivers as they flow out of that area?—Yes.

1826. Would that be a reliable test as to the net result of the rainfall due from that area, might it not be interfered with by springs flowing from the geological cropping out as it were or the overflowing of a basin which really collected the water in another area?—With reference to chalk, I should say decidedly not. Without going into the reason why, I think I may say decidedly that would not be the case. I think all the water from the chalk is due to the chalk; every spring that you find flowing from the chalk is water which is received on the surface of the chalk and flows from it. I never met with anything that made me think otherwise, except in this way, that where there may be a capping of gravel which has a seam of clay underlying it, sometimes a little water will flow out of it, but it will flow down into the chalk at the lip, or rather at the margin of this retentive stratum. There are such cases, as at Abbotts Langley in Hertfordshire, where there is a stratum of plastic clay overlying the chalk that upholds sufficient water to supply the inhabitants. Where it flows out in springs over the margin of the clay it at once sinks into the ground. I had a striking instance of that, I was measuring some wells with very great nicety, in order to see what effect certain pumping had upon the chalk water. I found that one of the wells was thrown as it were out of gear; it showed a height of water which I could not account for. I found that there was a pond in the bed of clay, the head of which had been cut, and the water let out. Directly it touched the chalk the water sank into the chalk, hence the water in the well had risen. So all along the outcrop of the tertiary strata there is water which runs into the chalk from the surface of the London clay, which sinks into the chalk when it gets to the junction of the plastic clay sand and the chalk through swallow-holes; that is the only exception I know; that is easily seen and accounted for, but I do not know any spring delivering from the chalk which derives its water at all directly from any other source but the water which sinks into the surface of the chalk itself.

1827. (*Mr. Prestwich.*) Do you consider that a large proportion of the rainfall passes directly into the chalk?—Yes, about one-third of the whole.

1828. If a large proportion of those claybeds cap the chalk hills, does not a certain proportion of the water falling on them pass into the chalk when it flows off those claybeds?—Yes, decidedly.

1829. How is this water which passes into the chalk delivered?—It is delivered again by springs wherever there is a valley of a river; wherever there is a place where it can get out it rises till it finds its outlet.

1830. Are the springs in the chalk area with which you are acquainted numerous?—Yes, very numerous; they are in valleys, and wherever they can get out they come out; they are very numerous and very strong.

1831. Besides that general issue of water on the line of the water-level in the chalk valleys, are there not springs of greater strength, such as the springs at Amwell, and such as the springs near Hungerford?—They are very strong indeed, and they are all to be accounted for by the contour of the country.

1832. Are you acquainted with any district where those springs are numerous, and such as would be capable of affording a large supply of water?—Yes.

1833. Can you mention any particular springs, or any particular place where such springs are common?—They generally come down the valleys in the way of streams; about Watford in Hertfordshire there is a spring yielding an immense quantity of water at a place called Otter's Pool; that is a very large spring from the chalk, and all down the valley of the Colne there are springs. I may express it in this way, that the rivers in the chalk run on the back of the springs.

1834. (*Sir J. Thwaites.*) It was suggested, was it not, some years ago that a supply of water should be

Rev. J. C. Clutterbuck.

13 March 1867.

obtained from the Watford basin?—Yes, it was proposed to sink large wells, and I had my attention first drawn to the question of water supply in the chalk in consequence of watching the effect produced by the pumping; I could trace the pumping every day; I knew when they were pumping and when they were not in that district; I have recorded the whole of that in a letter to Sir John Sebright.

1835. You think there could be no hope of obtaining a sufficient supply from the Watford chalk?—You would obtain a certain quantity, but it would be at the expense of the rivers; the rivers would cease to flow. When my advice has been asked I have invariably said, Take the water as it flows above ground, and do not tamper with it below; that is what I have invariably said, and I believe it is sound advice.

1836. (*Mr. Prestwich.*) I was asking you with regard to springs, not with regard to wells, whether you know of any springs of great volume and great strength in the area of which we have been speaking?—There is a very great volume and a very great strength at Amwell spring; I do not know the state of it at present because I have not seen it lately, but along all valleys in which rivers run, the Kennet, for instance, the chalk streams are fed from their sources down to the place where they deliver themselves into the river, because they run just on the springs, and are fed as they go. You may not see very large springs, but you will see an immense gathering of water in the course of the river by the discharge of the water from the springs.

1837. Do you know the spring near Hungerford or rather Froxfield?—I do not know that.

1838. Do you know the spring at Shalbourn?—I know the river but I do not know the springs; I attach less importance to individual springs than I do to the yield in the aggregate.

1839. (*Sir J. Thwaites.*) Are you of opinion, having regard to the condition of this watershed, that by proper catch-basins and engineering arrangements a sufficient quantity of water might be stored for the supply of the metropolis?—I have no doubt about it, taking the water as it flows down the river, not tampering with it by pumping or anything of that sort, and by an arrangement of storage in the upper districts such as those reservoirs which supply the summit level of the Oxford canal and other places, I believe there might be an immense storage of water in the upper districts.

1840. Which are the districts that would be most favourable for the formation of reservoirs?—The most favourable would be a district where the lower lias clay forms the bottom of the valleys.

1841. What part is that?—The district of which Banbury and Stow-in-the-Wold are the centres, having regard of course merely to the watershed of the Thames.

1842. As to the levels, you have, perhaps, not paid much attention to that branch of the question?—No, I have not had an opportunity; there is quite sufficient height to ensure their delivery.

1843. Would the point of their delivery be at high water?—Yes, they would be delivered into the rivers, and the rivers would be the means of delivering them into London. I have never contemplated the delivery of water into London from those sources at a higher level than the river itself.

1844. Then what would involve pumping of course?—Of course it would. You might, perhaps, by some very expensive contrivance, bring those rivers from their sources to London at a high level, but that would be a most extravagant way of doing it.

1845. Could you have sufficient fall?—Yes, you would have sufficient fall, but I think it would be a wild scheme.

1846. (*Mr. Prestwich.*) Would it not be possible to bring the springs from the chalk area to London from Buckinghamshire district at a high level in the same way that the new river brings water from the springs at Amwell?—Yes. There is no doubt whatever that the water from the chalk in many cases might be delivered into London at a higher level than it is at present.

1847. In the same way could you not bring water from the oolite hills of Oxfordshire and Gloucestershire, they being at a height of 200 to 300 feet above the Thames, and could not the springs from that district be brought to London by gravitation at a high level only at a greater cost?—Of course it might be done. I will not say anything about the cost.

1848. (*Sir J. Thwaites.*) Has your attention been directed to the probability of obtaining a supply of water for the metropolis other than from the Thames basin?—Yes; I have read the pamphlets of Mr. Bateman and Mr. Hemans with reference to that subject, which propose, the one to bring the water from the Welsh hills, from the sources of the Severn, and the other from the Cumberland lakes, projects which are well known, I believe.

1849. Does there appear in your judgment any serious objection, apart from the question of cost, to the schemes which have been generally considered?—One of the objections which struck me with regard to the scheme proposed by Mr. Bateman was, that he had not sufficiently shown that the watershed there would yield the amount of water that he calculates upon. In the first place he has not sufficient information with reference to the average quantity of rainfall, not that I attach much importance to the averages of rainfall. I think that all rainfall with reference to the areas which are to supply water to London must be considered with regard to the minimum, whatever that is—what shall be the minimum of rainfall, and what shall be the possible duration of drought which may deprive you of water at a certain time. The objection as it appears to me to Mr. Bateman's plan is that you have no certainty that you shall not at some period be deprived of water.

1850. Then your objection would be to taking an average at all?—Decidedly.

1851. And for the sake of safety you would take the minimum fall and all plus that would be gain?—The only thing to set against that would be the natural or artificial storage of water in those lakes, but when you speak of that as a supply of water which you are to depend upon you must take the minimum, as it appears to me.

1852. You are aware are you not that Mr. Bateman has allowed himself a considerable margin even below the average?—I am fully aware of that.

1853. Do you think that that reduction would be a safe one, on which the Commission might calculate that the yield would be equal to that which has been stated?—I should have some hesitation in answering that question, but the impression upon my mind is that there are deductions which perhaps people are not quite aware of, and that I would trust to nothing but a series of gaugings of those rivers which deliver the water, so as to get the net result.

1854. I suppose the gaugings in Wales have not been extended over a sufficient period to enable you to come to a conclusion?—I have perhaps read the pamphlet rather hastily, but I do not remember that there is anything like a gauging of the rivers mentioned, and without gauging the rivers I think you have no security, because you cannot tell in that country how much is evaporated, you cannot tell how much is absorbed, and there may be runnings of water which are delivered out at other levels that you know nothing of. It appears to me that in that peculiar structure of country there may be a leakage of water which you have not calculated upon. If it could be shown in a series of years that a certain river at a certain point yielded a certain quantity of water, then I think that you might deal with it, but I should be very much afraid of dealing with mere calculations of rainfall and area. No doubt the most reliable information would be to have the rivers gauged at their outfall, to ascertain the net result; that is much safer than depending upon any average rainfall. As compared with the chalk, you have no means of gauging the subterranean water, but I now gauge the subterranean water of the chalk by a line of wells in Hertfordshire, and am able to determine with very considerable accuracy how much water there is in the chalk; I have ascertained that

this year there is above the average quantity of water in the chalk to be delivered out, because I have measured that line of wells, and I find this will be the result. In a paper I wrote for the Agricultural Society there is a diagram of it, and I confidently rely upon that diagram, so much so that I have been able to tell within a day when some of those bournes would burst that there are in the upper district. I have been able to write to friends of mine in three or four different districts, and say, knowing that there was a certain quantity of rainfall, and knowing that those levels of wells had risen in a certain ratio, "You will find that your bourne shall burst within a week;" and it has been so. I have never been out in that calculation, and I feel as confident of it as possible; but you have no such means of gauging the waters which issue to a certain extent in the springs in those mountainous districts, and there may be a loss of water that you are not aware of, but if you have the gaugings of the rivers you can say decidedly that those rivers yield a certain quantity of water every year, that the average is so much, and you have never known them fall below a certain volume. I observe that Professor Ramsay thought there was always water enough in the rivers, but I know that there is nothing so deceptive as that. I have been told hundreds of times This is a spring that never fails, and it never varies. I say directly I know that that is not true. Here is the line of wells that I measured (*producing a section*). The lowest line is the level of the river, and the other is the line of water level. You cannot draw lines truer than those shall be. When I have measured one or two of the wells I can tell directly how much the ratio of variation is. As registered here it is 10 feet in one place and it is 1 foot in another. You can gauge the water in the chalk just as you can the water in a tub. I speak very positively upon that, and I am quite sure that I should be enabled to gauge the water in the chalk at any time, and I should be able to tell you that you should have a certain quantity at a given time. It is well known that Messrs. Dickinson, the great paper makers, make their contracts by a rain gauge. They have a gauge which registers that quantity of water which sinks through a certain amount of earth called "Dalton's gauge." I have tested it by the wells, and gauged the wells, and I can speak positively with reference to the probable yield of water from the chalk.

1855. You would not advise this Commission to be satisfied with merely obtaining information as to the amount of rainfall upon the theory that so much is absorbed and so much evaporated, but you think that we ought to have some information as to the quantity of water that flows off as the net result of all those operations?—Decidedly. I have not the least doubt about it as comparing the other districts with the chalk, I think that the chalk is quite different; you might go into the chalk at any time, having a previous knowledge of the condition of the water in the chalk, and you might gauge the water in the chalk; but I say it cannot be done in those other districts.

1856. (*Mr. Harrison.*) Your objection to Mr. Bateman's scheme appears to be based upon the ground that you do not think there would be sufficient water according to his calculation?—I am not satisfied that there would be.

1857. You have been present here while Professor Ramsay was being examined. Assuming that there are other districts, going northwards even as far as Bala Lake, and that it were practicable to bring double the area that Mr. Bateman has calculated upon into one and the same conduit for supplying London, perhaps you would not feel much difficulty in saying that a very large margin might be safely given to Mr. Bateman's calculation?—Yes, if you extend his area. I believe there might be an area so extended that you might have no doubt whatever upon the subject; but taking his area of 66,000 acres in each of those two plots, I should not be satisfied, if I were asked my opinion, that it had been proved to me that there was a sufficient yield; and if I were asked the reason why, I should say because the net result of the water from the district has never been put before me.

1858. Mr. Bateman has based his calculations upon the assumption that you could depend, even in a dry season, upon having 36 inches of rainfall available. Assuming that that should prove to be a mistake, but that he could add 50 per cent. to the gathering area, and bring it all into the same conduit, taking it in that case that you can only calculate upon 20 inches of water, do you think that we might safely calculate upon 20 inches of water in that hilly district from any knowledge which you have of it?—I should say that the probabilities were in its favour.

1859. You would not go further than that?—No, because I do not know enough of the circumstances of the district.

1860. But still, assuming that data really do not exist from any sufficient number of observations of rain gauges to find out the average at the present moment, and that Mr. Bateman has made all his calculations upon the assumption that you could have 36 inches available, if he could show that, in order to meet any possible deficiency, he could even double the area of his gathering ground, and bring it into the same conduit, that would at once get over the difficulty?—The probabilities would be in its favour. I could not venture to say more than that.

1861. (*Sir J. Thwaites.*) Having regard to Mr. Bateman's statement that the average rainfall in Wales is 48 inches, and that he struck off 12 inches from that as a margin for contingencies that could not be accounted for, do you think that 36 inches would be a fair and safe amount of water for us to anticipate from a given area?—I think it would be too much, but I cannot speak positively. My impression is that you would not get that quantity.

1862. (*Mr. Prestwich.*) In any case, should you not, as a geologist, look to the circumstance that in a district composed of absorbent strata the rainfall would be stored for the present, and delivered during a course of time, dependent upon the mass of the absorbent strata, whereas in a hard rock district, such as Wales, or in a slate district, should you not consider that the rainfall, not being absorbed, would be delivered immediately, and, therefore, would it not be necessary to take the minimum rainfall, and not the mean rainfall of a certain number of years for calculating upon the water supply of towns?—I would always take the minimum rainfall everywhere, but I would be more careful to take it in that district, because from the nature of the district, throwing the water, as we are presuming it does, from the surface, I am at a loss to know how you would get a permanent amount of water without an immense storage over and above what nature has given.

1863. (*Sir J. Thwaites.*) Or to provide for droughts?—Yes, your storage must be immense.

1864. (*Mr. Harrison.*) It is proposed by Mr. Bateman to provide very extensive storage, but it is a question whether he has provided enough, according to your view of it?—I do not speak so much of the storage as I do of the properties of the rain.

1865. (*Sir J. Thwaites.*) You are sufficiently acquainted, are you not, with the Welsh district, and also with the lake district, to form an opinion?—I know little about them. I know the general aspect of them.

1866. So as to form an opinion that they would be unobjectionable as a gathering ground?—I presume that they would yield you a water which would be very free from impurity. I have reason to believe that.

1867. (*Mr. Harrison.*) I gather from your remarks that you are decidedly against any question of pumping from the chalk?—Most decidedly so.

1868. If the Thames basin is to be used for getting pure water, you would go as near as possible to th fountain head?—Decidedly.

1869. Taking it from the springs arising directly from the chalk measures?—Yes; I cannot speak too strongly upon that point, it is a battle which I have been fighting for the last 25 years.

1870. (*Mr. Prestwich.*) Have you gauged any of

Rev. J. C. Clutterbuck.

13 March 1867.

the springs in the chalk area?—No, it is a thing I have never done, because I have always looked to the aggregate supply of water from a given stream. We know the Colne, for instance, and the Kennet, those two perhaps might give about the same quantity of water. And then there is another point which I have insisted on, and one which I have every reason to believe is well worthy of your notice, and that is the quantity of water which is received into the bed of the Thames itself. The little rivers which are in the chalk and which come down the valleys in the chalk, receive the drainage of a large portion of the chalk, but if you look at the map you will find that from Moulsford and down towards Henley there is a very large district which has no natural drainage at all, but it has its drainage into the Thames itself. Mr. Harrison, the brother of the Commissioner, asked me a good deal about that question, and it was a good deal with a view to that that I went and made a section to show the course that the water must flow into the Thames from there. Here is a little section (*producing the same*) from Streatley, something less than a mile up into the country. That lower line shows the mill-tail, the water lies in the chalk about 18 feet above the river, at less than a mile from it (*the witness explained the section to the Commissioners*). This shows that the natural drainage must be to the river.

1871. (*Sir J. Thwaites.*) How do you account for the difference of level?—Because the water always flows on an incline, I have seldom known it less than 14 feet in the mile and never less than 10 feet.

1872. Is it the retentive quality of the holding stratum that gives that difference of level?—It is the friction, it is the resistance that the water meets with in its passage through the interstices of the chalk which makes it take that incline; that is the balance of the friction and hydrostatic pressure. For instance, if you pump from a shaft in the chalk you will find that the water around it is depressed in the form of an inverted cone; you will find that the first foot or two will come down very easily, but inasmuch as you increase the pressure of the water into the shaft, as you get lower down the water will be reduced very slowly, and at last if your pump is not very strong it will be reduced to a point at which it will stand, so that you may pump away, and it will not vary an inch for a long time. Then if you take the pumps off, the water will rise in the shaft in the inverted ratio of its reduction. The natural rise and fall of the chalk water is so beautifully regulated that you may rely upon the chalk gaugings when you cannot rely upon any gaugings in other strata.

1873. (*Mr. Harrison.*) The terms of the Commission point, I might almost say confine the Commission, to the idea of obtaining water from grounds by gravitation, so as to afford a constant high level supply to London; that being the case the views which you have given as to taking the water from the springs in the chalk would hardly be available to carry out that idea, but taking the higher level of the Thames could you give us any idea as to this; assuming that 400 feet above Trinity datum was the minimum point at which you would have to take those waters, would you get a sufficient watershed to supply the consumption of London at the rate of about 250,000,000 gallons a day?—No, certainly not.

1874. Could you give any idea of what that 400 feet would supply?—No, I could not warrant anything at 400 feet.

1875. (*Mr. Prestwich.*) Except the small tributaries?—No, besides that if you did that you would be, if I might be allowed to say so, robbing the Thames; you would reduce the Thames very much.

1876. (*Mr. Harrison.*) Possibly we might take a less height than that, say 300 feet, what would it be?—I do not think that would be worth having.

1877. Then the result practically would be this, that it would be impossible to comply with what the terms of the Commission seem to press upon us, namely, to supply water at a high level by gravitation from the Thames basin at all?—Decidedly.

1878. (*Col. Harness.*) How do you arrive at any extent of gathering ground which would be above 300 feet?—For this reason, the source of the Gade is 365 feet only above Trinity high-water mark. You mean that you are to draw it from sources 300 feet above Trinity datum; Bury Mill, the second mill upon the Gade, is the first mill which seems to have a constant supply of water, it is only 279 feet above Trinity datum.

1879. (*Mr. Prestwich.*) At what distance is that from London?—In a straight line; I should think it was 23 or 24 miles.

1880. (*Col. Harness.*) Is the Gade the draining stream of the highest portion of the basin?—I do not think there is much difference in the chalk waters. The Kennet delivers itself into the Thames at about 120 or 130 feet above Trinity high-water mark—not more than that—and then you have to calculate how much fall you get to the source, and I do not think that you will get more fall than you do in the Gade. You might get a certain proportion as you go further up. I think that there are none of those streams that you can depend upon, because you cannot depend upon the water; it will not do to go to the upper sources, which are sometimes above ground and sometimes below, you must go to where you can get water at all times. I am sure that you could not get it at 400 feet, and I do not think that you could get much at 300 feet.

1881. Some of those upper streams in oolites are lost occasionally are they not?—Some of those streams are; there is a very remarkable case in the river Churn. One very dry season, I think it was in 1858 or thereabouts, I believe the millers on the stream thought there was some tampering with the upper springs which deprived them of water, and they had a very elaborate and expensive investigation, and it was proved that the river absolutely lost nearly all its water before it got to the Thames, so that you cannot reckon upon it. Where it goes to we cannot say.

1882. (*Mr. Harrison.*) The investigations were made by Mr. Simpson I believe?—Yes. So that you must take the Churn out of the list. I forget now what is the height of the upper level of that canal, the Thames and Severn canal. I am positive that it is not much more than 300 feet above Trinity datum. The height is 330 feet above the sea, or 317 feet 6 inches above Trinity datum.

1883. It is more than that, my impression is that it is about 430 or 440 feet, speaking from memory?—I think you will find the height I have given is correct.

1884. (*Mr. Prestwich.*) You are acquainted probably with springs such as those at Barton at the foot of the chalk hills in the clays and again beyond Ashridge. All of those springs rise at the height of 400 feet above the Thames, and there is another near Hungerford which is also about 300 feet above the Thames. Therefore, without looking to a very large source of supply, a supply of an extent sufficient for the total amount required by London,—is it not possible to find in such springs a considerable quantity of water at a height that will allow that water to be brought to London by gravitation and of a quality sufficiently good for such purposes of supply?—I would not trust to 300 feet.

1885. You consider then that it would be necessary to draw a contour line round the country?—I cannot speak as to the level sufficiently, but my impression is that 300 feet would be too high. I think that you might take 200 feet.

1886. (*Mr. Harrison.*) Even up towards the higher sources you would go a little higher?—Yes, you would find water a little higher, but whether you would find enough I cannot say, on such as you could rely upon.

1887. (*Mr. Prestwich.*) In fact you have not sufficiently gauged those streams or ascertained their height to give a positive opinion?—No.

1888. It would require a complete survey in order to establish those points?—Yes; my impression is that you would find that the most reliable sources after all were in the chalk.

1889. With regard to the quality of the water I

think you spoke of chalk water being very hard ?—Yes, it is hard no doubt.

1890. But you do not consider it an extreme degree of hardness ?—No, there is nothing that I should object to.

1891. Have you compared it with the water from the oolites ?—I think that the oolite waters are more objectionable than chalk waters, but I would rather not speak to that, that is a chemical question to which I would rather not speak.

1892. (*Mr. Harrison.*) You have been accustomed to hard water all your life ?—Yes.

1893. (*Mr. Prestwich.*) As you have always lived in a chalk district and drunk the chalk waters have you ever found any ill-effects from the uses of them ?—Not the least.

The witness withdrew.

ROBERT RAWLINSON, Esq., C.B., further examined.

R. Rawlinson, Esq.

1894. (*Sir J. Thwaites.*) You are desirous, are you not, of adding some little matters to your evidence which you gave to the Commissioners on a previous occasion ?—Yes, some questions were asked at the time I was in the room, with regard to the use and utility of iron service pipes in soft water districts—as compared with lead pipes. I think that Professor Way had not the means of giving an answer to the Commissioners upon that subject so fully as I have if you choose to take replies from me upon that point.

1895. The question arose as to the effect of soft water on iron pipes whether fully charged or upon the intermittent system ?—I am not sure that I gathered rightly that any of the members of this Commission were in doubt as to whether wrought-iron was a proper material to use for house service.

1896. I do not think that any member of this Commission would raise any doubt about it?—There is great doubt, however, expressed by persons outside, iron has been very strongly objected to, and both engineers and architects have repudiated the use of wrought-iron, for several reasons ; first, because they said that it would not stand in use ; secondly, because it was so difficult to manipulate ; and thirdly, that if repairs are required, it is very difficult to repair, on account of its being much more rigid than a lead pipe which can be cut anywhere. I have had an extensive experience in the use of wrought-iron pipes ; it has become, perhaps, almost a mania with me—I will not use lead, and I will not recommend the use of lead. I have supplied with wrought-iron services pipes the towns of Berwick-on-Tweed, Alnwick, Morpeth, Ormskirk, Worthing, Keswick, and Lancaster, and in some of those towns they have been in use 10 or 12 years. The waters of Lancaster and of Keswick are as soft as any waters in the world. The Keswick water comes from the clay slates of Skiddaw, and the Lancaster water comes from millstone grit above Lancaster. Professor Playfair told me that the sample was more like distilled water than natural water, for he had never previously met with natural water so pure. I have not yet heard of mischievous effects of any kind being produced by the use of that water.

1897. How long have the pipes at Lancaster been laid down ?—Ten or 12 years.

1898. Have you examined them ?—No I have not personally examined them, but I have had reports of them, and I think I should have been certain to have heard if they had been disparaged ; I have written for the purpose of knowing how they have stood the frost, as also how they have worked, and I have had no complaints about them.

1899. Have you ever heard of any complaints that the softness of the water was acting upon the iron ?—I think I heard some complaint about a portion of the Keswick pipes, but that was during one summer, when the water was short, and the pipes were alternately filled and emptied during the whole summer, which was a peculiarly dry one, and the source of supply did not meet the demand. Since then we have added to the sources of supply, and I have heard no further complaint.

1900. You account for the action on the pipes by the admission of the atmosphere ?—Yes, if you alternately fill and empty a wrought-iron service pipe, corrosion will be set up.

1901. In your judgment, iron pipes constantly charged with soft water would not be affected ?—Speaking from some years experience, I say they are not affected. Then with regard to their cost they are cheaper than lead, and with regard to their strength they are far stronger, in proportion as iron is stronger than lead. With regard to the facility of fitting them, I have made ordinary labourers into expert fitters. Of course it requires a certain intelligence and knowledge of what you are to do before you commence. The plumbers in supplying a house can bend lead pipes anywhere. In iron pipes there are bends, elbows, and T pieces. A vice, a saw, a file, with taps and dies will give you new screw ends, and you can shorten, lengthen, and turn them round anywhere ; you must put means of escape for air which will accumulate at any up-bend.

1902. When you speak of wrought-iron pipes, you mean the drawn pipes as contrasted with the cast ?—I mean what is known as the best gas tubing. I wish to remark that galvanized pipes are not to be recommended. They cost 40 or 50 per cent. more than plain pipes, and the galvanizing is a delusion. If the pipes are laid in subsoils which will act upon iron, the galvanizing affords no protection against that action, and there are soils which will rapidly eat away either iron or lead.

1903. The galvanized iron is put into boiling zinc or something of that kind, is it not ?—Yes ; but if you examine it under a microscope you will see that it is not an even coating, it is freckled, and there are interstices, oxidation sets up and then the galvanizing is blistered off.

1904. However it would not injure the pipe I apprehend ?—It does not improve it.

1905. And so far as it does cover it it preserves it ?—No, I very much doubt that. It is not stronger in its texture and it certainly does not last longer, that is my experience.

1906. (*Mr. Prestwich.*) When Professor Way gave his evidence, I was under the impression of having read that the waters at Grenoble, where they are very soft, had acted upon the iron pipes and led to the necessity of their all being replaced after a lapse of some 10 or 12 years, but I was not prepared with the exact data or the particulars. Since then I have written to M. Belgrand, the chief engineer of the water supply to Paris, for information upon the subject, and I received a letter from him yesterday in which he refers me to publications where all the details are given, but which I have not yet had time to go into. He, however, informs me that at Grenoble the soft water did produce tuberculous concretions upon the pipes, which led to the necessity of their being removed after the lapse of a few years, and he further says that at Cherbourg the same result was produced ; that circumstance led to a series of inquiries by M. Belgrand and others, and he states that the result of those investigations was that waters chemically pure do not always produce ferruginous tubercles as the first observers believed. Have you information that you can give us upon this subject ?—In Whitehaven soft water from Lake Ennerdale acted on cast-iron pipes, and in a very few years those of small diameter (3-inch) were all tubercled, corroded, crusted up, and filled with oxidised matter, but nothing of that kind has ever occurred in a town that I have had to do with, certainly not in

R. Rawlinson, Esq.

13 March 1867.

Lancaster nor in Keswick. The Whitehaven pipes, I may observe, were laid down without any preparation, whereas I have never used cast-iron pipes without subjecting them to Dr. Angus Smith's process of preservation. The pipe is taken from the sand in the foundry, it is cleaned and fettled, and before oxidation is allowed to set up, it is heated to about 500 degrees, and is dipped into a bath of composition of gas tar, Burgundy pitch, and oil, and I believe a little resin, in certain proportions which are described. Then the pipes are raised up and the surplus matter runs off, and if the operation has been done at a proper heat and under proper conditions each pipe has an exquisite black varnish inside and outside as if it were the finest black paint varnish, and that, I believe, is one cause of success in preventing oxidation from setting up. But there is another point with regard to soft water, which is of far more importance, and that is lead poisoning. Beyond all question of a doubt, and I am speaking now from information which I have received both in Manchester and in Liverpool, lead poisoning has taken place since the introduction of soft water into those two towns, and there are medical men who could give evidence upon the point, Dr. Angus Smith and Dr. Crace Calvert, of Manchester, expert chemists, have had cases brought to their attention.

1907. (*Mr. Harrison.*) Mr. Bateman adopted that plan of varnishing in his Glasgow works, did he not?—Yes, but first of all in Manchester.

1908. (*Col. Harness.*) Your opinion is not that water does not act upon iron but that iron can be so protected that water shall not act upon it?—I have never laid down cast-iron mains without this varnish. Cast-iron mains that have not been varnished, if they have laid five or six months on the ground, become oxidised both inside and outside, and pure water coming in contact with the commenced oxidation carries it on more rapidly. If you lay a varnished pipe six months on the surface it shall not show one particle of rust except where it has been scratched or abraided by rubbing the varnish off.

1909. (*Sir J. Thwaites.*) Have you any experience of the effect of friction upon that varnish, whether it is soon removed or not?—I think not. As the pipe is heated a certain portion of air is driven out from the pores of the iron and then as it cools in the varnish the pores absorb a certain amount of the varnish, which may for anything I know chemically combine with the iron. At all events where we have cut pipes in Lancaster, after eight or ten years service we have found no such blistering as that spoken of at Whitehaven, and as that mentioned in the letter of M. Belgraud.

1910. Would not the flow of the pipe itself be increased by that smooth surface, and the friction be lessened?—I think not. I think that the best mathematicians now know that water flows upon water, and whether the pipe is absolutely smooth or not is not of so much consequence as was once thought if the full diameter is preserved.

1911. (*Mr. Harrison.*) Mr. Bateman stated that in the case of the Glasgow water works he found the discharge from his large pipes very much greater than the ordinary calculation would give, that of course one can quite understand from the fact that all experiments and all formulas are based upon experiments with small pipes, but he also stated this, that since the opening of those works the discharge had been gradually diminishing, is it not probable that that must arise from some alteration in the pipes?—He has some pipes 48 inches in diameter, and it would be a very difficult process to keep those pipes constantly full, as you are aware, water carries in a certain amount of air, that liberates itself and rises to the surface, there are upon all large mains air-valves affixed at up-bends or points to discharge that air; but I have no doubt that a great deal of it plays backwards and forwards, and in parallel mains, if there is much head or fall in the pipes, vaccuums are formed in the pipe by the delivery velocity being greater than the receiving head can take in. For instance, a pipe, say 12 inches in diameter, laid at a grade of a quarter to one, with the delivery under 200 feet head, you have a valve at the lower end, screw it down, and your pipe is full. Open your valve and a gush of water comes out at the first, then it absolutely stops, then another gush comes, and it goes throbbing on for a considerable length of time until friction and gravity have balanced each other, but I believe in that pipe you will find a series of vacuums, that the water is delivering itself by gushes faster than it can get in, and it is the pull upon the vacuum that causes the water to pulsate.

1912. (*Mr. Harrison.*) Have you ever had any difficulty with soft water in reference to your taps and cocks in keeping them tight?—None at all. I insist in all cases upon the wrought-iron pipes having screwed joints and the taps having screw means of fastening, and I require that the tap should be what is known as a screw-down tap, such as those made by Messrs. Guest and Chrimes, Messrs. Lambert, and others, in which all the parts are screwed. You can easily instruct an ordinary labourer, if he is a man of intelligence, to repair such taps. A man would take in his bag or his pocket half-a-dozen three-eighths of an inch taps for cottage service—and a three-eighths tap is quite sufficient, if you have 100 feet pressure, and constant service,—he would screw down his stop tap outside, unscrew the unsound tap, and screw on a sound one. He would do it almost while I am talking about it, namely, leave a sound tap, and take the leaking one home, and there set it to rights. It is generally the leather that has got cut that causes the leaking. The man would repair it at his leasure, and make it a sound tap again. By those means local authorities are enabled to economise water, because when you talk of 20, 30, 35, 40, or 50 gallons per head, you must always consider that you are not talking of supply; you are talking of waste, and the higher up you get in the scale, just in proportion is that waste. I am certain that out of 100,000,000 of the gallons passed into London, 50,000,000 gallons of it are not legitimately used. All over the West End ball taps are deliberately propped up, or taken off, because of the intermittent supply. And, again, I must say that there is very culpable negligence on the part of the water companies; they do not seem to care about wasting water. I can point to places in South Kensington, which I have passed for the last 15 years, where there are stand pipes and valves. I have sometimes seen a channel of waste water that would have filled a three-inch pipe wasting for weeks and weeks together. Whether much or little of that water went through the subsoil and so into the sewers, for the subsoil is gravel, I cannot tell.

The witness withdrew.

Adjourned to Wednesday next, at half-past 11 o'clock.

Wednesday, 20th March 1867.

PRESENT:

SIR JOHN THWAITES IN THE CHAIR.

Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

THOMAS HENNELL, Esq., examined.

T. Hennell, Esq.
20 March 1867.

1913. (*Chairman.*) Are you a civil engineer?—I am.

1914. Are you engaged on any works at present?—I have been assistant engineer in charge of works, and I should be now, but that the works are temporarily suspended.

1915. Are you in charge of any works yourself?—Not as engineer in chief. I am in charge of works as resident civil engineer; as sub-engineer.

1916. Have you ever carried out works on your own account?—No.

1917. Have you ever advised any public body with reference to works of engineering?—No, I have not.

1918. How long have you been a civil engineer?—For nearly eight years; I mean it is eight years since I finished my articles.

1919. You have had your attention directed, have you not, to the subject of the conveying of water to London?—Yes.

1920. In what capacity?—By several of my friends at Basingstoke, who are interested in the Basingstoke canal, my attention was called to the large supply of water they had, which they did not use, and also to the general difficulties of the canal company, and I was asked whether I thought anything could be done for them, and whether any use could be made of the water, and in consequence of that I was led to consider the project of carrying it to London.

1921. What was the result of that consideration?—The result of that consideration is, that I find that 14,000,000 gallons a day for certain can be obtained from the canal, and from sources almost close to it, and can be conveyed to London at a very moderate cost.

1922. (*Mr. Prestwich.*) From what part of the Basingstoke canal could you get those 14,000,000 gallons?—12,000,000 would come from the first eight miles at the Basingstoke end, and about 2,000,000 more from the district of the Bagshot sands between Farnborough and Woking.

1923. Your first district would be chalk?—Yes, my first district would be chalk.

1924. Through what length of chalk area?—I have not taken out the area, because I do not know what the drainage area is.

1925. Through what length of chalk district does the canal pass?—About eight miles.

1926. (*Chairman.*) When you speak of the canal, is it ever used now for canal purposes?—It is used as a canal now, but the company are in very great difficulties. It hardly pays its working expenses, and the company is in chancery.

1927. Your proposal I presume, would be to purchase the interest of the canal company?—Yes.

1928. And to utilize the canal?—To turn it into a conduit for the conveyance of water to the metropolis.

1929. Have you directed your attention to the watershed for the purpose of ascertaining whether it is possible to add to the 14,000,000 gallons?—Yes, I have, I have no doubt whatever that it can be very largely added to. In the first place with regard to the chalk water, I have only taken one-third away from each of the branches of the Loddon, and of course a much larger amount can be taken if proper compensating reservoirs were constructed, or if the interests of the millowners on the river were bought off. Then again with regard to the other parts of the canal, I have neglected the part between the termination of the chalk, which is near Odiham, and Farnborough, because it is all agricultural land, and I imagine that the surface draining would not be worth having; but with regard to the part between Farnborough and Woking, that consists of the Bagshot sands which yield very good water; they are not cultivated, and there is a very large district of something like 20 or 30 square miles which is above the level of the canal, and all the waters of which would probably be collected by proper intercepting conduits.

1930. I suppose you would form reservoirs for the purpose of storing the storm-water, in order to compensate the river for that which you abstracted?—Yes, certainly.

1931. Giving an equal flow to the river from your reservoirs?—Yes, giving an equal flow to the river to what it has throughout the greater part of the year.

1932. If that arrangement were carried out, would it interfere with the interest of the millowners?—I do not think it would. I think they would be relieved from the surplus waters in the flood season, and they would certainly have no water taken from them in the dry season.

1933. They would have water added to them?—They would have water added to them in the dryest season.

1934. What is the discharging capacity of that canal at present?—I believe the springs in the canal and two or three little streams which at present lead into it yield about 3,000,000 gallons a day.

1935. I am speaking of the structural form of this canal; what is its capacity to convey, you say it does convey 14,000,000 gallons?—I say that it can be made to do so, by being turned into a conduit.

1936. Do you propose to alter it?—I propose to form a paved brick channel throughout the whole length of the canal.

1937. Do you propose to increase the size of the canal?—No, I propose to diminish it.

1938. There are a great number of locks, are there not on that canal?—There are 29 locks altogether.

1939. You would be obliged to retain those locks I suppose?—I should get as much fall as would be desirable between the locks. I should not allow the fall to exceed four feet per mile, and that would diminish the height of the locks and the remainder would form a weir.

1940. How do you propose to line it, giving it a four-feet fall?—I propose to adopt several different kinds of section according to the amount of fall to be obtained at different places. Here is a section with two or three specimens which may be adopted in different parts (*producing the same*).

1941. Do you line it with brick?—With brick paving on concrete, taking 9 inches of concrete as an average.

1942. What in your judgment would be the utmost extent of water which could be fairly calculated upon to be obtained from that area?—Supposing the whole were taken from the Bagshot sands, as mentioned in the reports of Mr. Bateman and other engineers in 1852, I believe there are about 7,000,000 gallons to be obtained there.

1943. That is in addition to those 14,000,000 gallons which you have already mentioned?—Yes, in addition to the 14,000,000, and with regard to the chalk water, I imagine that amount might be increased; it is entirely a question of compensation to the millowners. If the whole were taken from the river it would amount to about 30,000,000 gallons instead of 12,000,000.

1944. Do you know the number of mills on those streams?—I do not know the number, but I can count

T. Hennell, Esq.

20 March 1867.

them if it is desired; they are all shown on the Ordnance map.

1945. They are very numerous, are they not?—Yes, there are a very great many.

1946. That would make 21,000,000 gallons which is a very small portion for the supply of the metropolis?—I only propose this as a scheme in extension of the present system of supply, that is all.

1947. (*Col. Harness.*) Where is the summit level of the Basingstoke canal?—The head springs are at Greywell about six miles from Basingstoke.

1948. What is the summit level of the canal itself?—There is one long reach from Basingstoke to Aldershot, and the whole of that long reach forms the summit level.

1949. Do you remember what is the level of it above high water?—It is 252 feet above Ordnance datum at Basingstoke.

1950. (*Chairman.*) Have you made any estimate of the probable cost to purchase the canal?—Yes, that I have done, and I should just mention that in the statement in the hands of the Commission I put down 260,000*l.*, which included everything but the purchase of the canal. I had not the means at hand at the time of supplying that, but I have been able to do so now. I put down 20,000*l.*, and I have good reasons for adopting that sum for the purchase of the canal, and 260,000*l.* for works.

1951. Where does that canal terminate?—It joins the River Wey, near Weybridge.

1952. Then there would have to be a conduit?—Yes, then I should have to convey it eight miles to the existing reservoirs at Thames Ditton.

1953. And that is included in the 260,000*l.*?—Yes, and that I propose to do by a covered channel.

1954. That should be in tunnel, I presume?—Yes.

1955. Above the surface or what?—For a short distance opposite Weybridge where there is a very considerable hill it would be in a cutting varying from 20 to 40 feet deep for about two miles, for the remainder of the distance it would be just below the surface.

1956. (*Col. Harness.*) What is the level of the basins at Thames Ditton, where you propose to take it?—The level of the river.

1957. To whom do the basins belong?—They belong to the five water companies, who take their water from the Thames now.

1958. (*Chairman.*) Does that 260,000*l.* include the reservoirs for compensating the rivers?—It includes the compensation and storage reservoirs.

1959. Have you any section of the reservoirs?—I have a plan of the largest reservoir, with the levels from actual survey (*producing the same*); 112 acres is what I have taken, and 40 acres is shown on the plan as a possible extension.

1960. What rainfall have you calculated as being due from this area?—I have not taken the chalk waters by rainfall at all.

1961. The plan that you have put in shows a section of your embankment, and also the area of your reservoir, amounting in all to 112 acres and 40 acres. The holding capacity, I presume, would be 840,000,000 gallons?—Yes.

1962. And 250,000,000 gallons would be that of the 40 acres?—Yes.

1963. What depth is your dam?—43 feet is the height from the ground to the surface of the water, and the bank would be four feet higher.

1964. Do you make one part of clay puddle?—Yes.

1965. Of what is the other portion constructed?—The other would be constructed of a material which is a mixture of loam and sand. The whole reservoir would require lining.

1966. How do you line the surface?—The surface would be lined with puddle about one foot in thickness. I have allowed for that. There is a mixture of sand and clay, and possibly it might not be required to be lined throughout.

1967. Do you know of any embankment of this character and height formed with a material of that loose porous description?—I do not know of any, but it is a material that stands at a very good slope on railway cuttings.

1968. You give it a slope of 3 to 1, do you not?—Yes, on the inside.

1969. But supposing the water were to break your lining, through the clay into the sand, what would be the result; would not it blow up?—I suppose the water would find its way through gradually, if it did break the lining.

1970. (*Mr. Prestwich.*) The water would all escape in that case?—The lining, of course, must be made perfect; it would depend upon that.

1971. Are there no materials in the neighbourhood of which this could be made without having resort to sand?—There is clay to be obtained within four miles of that spot.

1972. That would add very much to the cost, would it not?—Yes, if the whole embankment were constructed of it, of course, it would add very much to the cost.

1973. Have you no stone of any kind in the district?—There is no stone there.

1974. What is the extent of the drainage area of the gathering ground?—As far as the chalk is concerned, I have taken it from the gaugings of the springs. I believe that the rainfall is 24 inches, but I have not founded my calculations upon that.

1975. Have you gauged the streams running from that district?—Yes.

1976. What is the net result of that in inches of rain?—That I am unable to give, because I have not taken out the area of the gathering ground. I do not know where the springs come from. I could not draw a line so as to say what particular ground supplies particular springs.

1977. But you know where you expect your water to come from?—The water comes from the springs which issue on the margin of the chalk for eight miles.

1978. And these depend upon the rainfall?—Yes, that is dependent upon the rainfall on a very considerable extent of country; but it is impossible to say exactly what extent.

1979. How do you calculate that you will get this 840,000,000 gallons of water?—840,000,000 is 60 days' supply at 14,000,000 gallons a day.

1980. That is the supply for your conduit?—Yes, the 14,000,000 gallons consist of the 12,000,000 gallons from the chalk that I have obtained by gauging the actual springs themselves, and 2,000,000 are from the sand district.

1981. Have you gauged the streams?—Yes.

1982. You have calculated the annual rainfall at 24 inches, I believe?—I have not founded my calculation upon that, but I believe that is so.

1983. Having regard to the gaugings that you have made of the several streams, what depth of rainfall would that account for?—To answer that question I must know what the area is from which the springs are supplied, and that I have no means of getting, because there is a large extent of chalk hills, and there are springs on one side of that range of hills, and there are springs perhaps 8 or 10 miles off on the other side, and I cannot draw the line so as to say which part of the country supplies the springs on the one side or the other.

1984. Then your attention has been directed rather to the springs than to the gathering ground that would feed those springs?—Yes.

1985. You are not able to state to the Commission what the amount of evaporation or what absorption of rainfall would be?—No.

1986. (*Mr. Harrison.*) Referring to your section of course, the height and slope of the embankment would depend upon the material of which it is made?—Yes; there is only a very short extent of that deep bank, about eight chains; around the rest of the reservoir the general height of the bank is 10 feet.

1987. Those waters now all flow into the Thames, do they not?—Yes, they do.

1988. Therefore your proposal to intercept at their source the waters that now flow into the Thames, would in effect be merely taking water from the Thames?—That would be so no doubt, but at the same time there is a very great loss of water in the canal itself. It leaks at almost all the embankments, and the greater part of the water so leaking gets on to the land, and is lost by evaporation in a very great measure.

1989. Still your project may be taken simply as a plan for taking the water at its source before it flows into the Thames?—Yes.

1990. But still adding to the quantity that is now taken from the Thames, the water that you bring to the general reservoirs, and there mixing it in a purer state with the existing water of the Thames?—I hardly suppose that the same reservoirs would be used, but other reservoirs in the same place.

1991. But with regard to distribution, you propose to distribute this water, do you not, by the same pipes, and, therefore, the waters will become mixed in that way?—Yes; but then I take the water in the flood season, and the existing companies take the water from the Thames when they want it.

1992. It comes to this, that you would merely propose to introduce a certain amount of water in a purer state than what it may be taken to be in the Thames, and to mix it for distribution with the present supply from the Thames?—That would be so if this scheme were taken up by the existing companies at Kingston, but the mixing of the water would only take place if it were divided between several companies. There are at present five companies distributing on the average about 10,000,000 gallons per day each; the proposed supply of 14,000,000 would be an ample supply for any one of them to use exclusively, and, if extended as suggested, might in like manner be made available for any two.

1993. You do not propose to have a new system of distribution for so small a quantity of water as your scheme would supply?—I have not proposed that, but it is possible of course that it might be done; and as one instance, I may mention that there is a company this year who have deposited a scheme for making a reservoir within a short distance from the Thames, and taking a fresh supply; and that company or any other company similarly situated might take the whole of what I propose to bring there, and leave the Thames alone.

1994. Still the distribution would be by means of one of the existing water companies?—Yes.

1995. (*Mr. Prestwich.*) Have you had these waters tested or analysed?—No, I have not. I have no doubt that they are very similar to the other chalk waters of the same district. The Farnham branch of the river Wey, which rises about eight miles from some of the sources which I have mentioned, is of 14 degrees of hardness.

1996. But you propose, do you not, to take water not only from the chalk, but also from the Bagshot sands?—A small quantity from the Bagshot sands.

1997. Therefore the mean of the water would be less?—Yes.

1998. And that you would obtain probably by the waters in the canal as it passes through that district?—Yes.

1999. You say that from Basingstoke to Aldershot the canal maintains a uniform level, and that there are no locks?—Yes.

2000. Consequently, at Aldershot, you are at a distance of about 30 miles from London, at height of 250 feet above London?—That is so.

2001. Therefore the water might be brought to London by other means than by the culvert which you propose, or bringing it along the canal, and be delivered in London at a very much higher level?—Certainly it could.

2002. (*Mr. Harrison.*) Taking the distance as 35 miles, what should you consider to be the necessary fall per mile through those pipes in order to overcome that friction for distribution, at a height, say of 200 feet, in London?—That would depend upon the amount of the piping. If it were an open channel, such as I propose to make, and the country would allow of an open channel for a considerable part of the length, it could be done with a fall of six inches to the mile for that part.

2003. Your plan, as I see by the section, is to come directly down into the valley?—My plan is to make use of the canal, undoubtedly thereby losing a certain amount of power.

2004. (*Chairman.*) As I understand, you propose to discharge your water at the level of the Thames, at Thames Ditton?—Yes.

2005. (*Mr. Harrison.*) Therefore it would have to be pumped up again for delivery in London?—Yes.

2006. (*Chairman.*) As a practical question, you are intercepting the waters at a higher point, and bringing them so many miles to Thames Ditton, instead of allowing them to flow into the Thames and become polluted, as the present water is, and to give auxiliary aid to the several companies at that point?—Yes.

2007. And there the waters must be mixed with the other waters of the Thames to supply the metropolis?—Yes, or used by one or two companies only.

2008. (*Col. Harness.*) Where do the Canal Company derive your waters from now, from the supply of the reach at the summit level?—From springs in the neighbourhood of Greywell.

2009. What quantity of water can they supply?—They supply, as far as I have been able to ascertain, about 2,500,000 gallons per day.

2010. Do the Canal Company receive it into the reservoir and store it?—No, they do not.

2011. Do they draw it into the summit level as it is wanted?—Yes, they draw it as it is wanted; they have sluices at different places to let off the surplus.

2012. (*Mr. Prestwich.*) Besides those wells at Greywell, do you consider that the canal intercepts springs between Greywell and the point where it leaves the chalk district?—Yes, it does; it intercepts the principal source of the rivers Loddon and Whitewater.

2013. Have you any knowledge of the quantity of water that is delivered by those springs?—Yes, I have. To take first the Whitewater; that I found in October contained, in round numbers, 10,500,000 gallons. I propose to take one-third of that, and that is rather the largest of the three principal sources.

2014. Where is this?—That is the river Whitewater, which is almost close to Greywell; it rises about half a mile above Greywell, and it discharged 10,500,000 gallons on that day in October, of which I propose to take one-third. I measured the stream again last week, and I found 14,500,000 gallons daily. Then, in addition to that, there are the Mapledurwell and the Newram springs within a mile of Basingstoke.

2015. Can you state the volume of those springs?—The Mapledurwell springs contain 1,980,000 gallons. There are springs east and west of the village; those which are on the east side of the village I cannot conveniently take, because they are at a low level, but they unite afterwards, and therefore I take two-thirds of the western springs only, which would be equal to one-third of the whole. They unite before they come into any stream where they would be required, and therefore I take two-thirds of 1,980,000, that is 1,320,000. Then the Newram springs contain, in round numbers, 4,500,000, of which I take two-thirds; that is 3,000,000.

2016. What is the total quantity of all those springs?—The entire total is 28,296,000.

2017. Does the canal intercept springs at the level of the canal?—Yes.

2018. Therefore the water would flow into the canal in all those cases?—Yes.

2019. (*Chairman.*) Have you made any estimate of your works?—Yes.

2020. Can you hand it in?—Yes, I shall be happy to do so.

T. Hennell, Esq.

20 March 1867.

The witness delivered in the following paper:

ESTIMATE.

	£		£	s.	d.
Adaptation of Canal:					
Newram springs to Greywell tunnel, 4½ miles. Section No. 1[a]	1,400	per mile	6,300	0	0
Greywell tunnel to Aldershot, 13¼ miles. Section No. 2	2,801	„	37,113	0	0
Aldershot camp, 1½ miles. Covered section	6,160	„	7,700	0	0
Aldershot to Frimley lock, 5⅝ miles. Section No. 3	2,530	„	13,598	15	0
Frimley lock to proposed reservoir, 2⅛ miles. Section No. 1	1,950	„	4,143	15	0
Reservoir to first lock (from river Wey) 7 miles. Section No. 4	1,600	„	11,200	0	0
			£80,055	10	0
Newram springs:					
Compensation reservoir to hold one month's supply of 3,000,000 gallons daily, with land, and cut from springs to canal			10,000	0	0
Mapledurwell farm springs, cut			1,000	0	0
River Whitewater:					
Compensation reservoir, sluice gates, &c.			10,000	0	0
Protection of Mitchet Lake and other ponds near Pirbright			2,500	0	0
Storage reservoir at Brookwood:					
Land; 120 acres at 40*l.* per acre	£ 4,800	s. d. 0 0			
Puddled bottom; 538,500 superficial yards at 1*s.*	26,925	0 0			
Embankment: 420,000 cubic yards at 9*d.*	15,750	0 0			
Puddle wall; 48,200 cubic yards at 3*s.*	7,230	0 0			
Embanked approach:					
Seven acres land (including for side cutting)	280	0 0			
18,360 cubic yards at 9*d.*	500	0 0			
Sluice gates, &c., and diversion of road	2,000	0 0			
			57,485	0	0
[Estimate for the larger reservoir, 70,274*l.*]					
First lock on canal to Weybridge:					
4,400 lineal yards fencing at 2*s.*	440	0 0			
116,000 cubic yards embankment from side cutting at 9*d.*	4,350	0 0			
2⅛ miles channel (Section No. 4[a]) at 1,600*l.*	3,400	0 0			
Syphon under river Wey	1,000	0 0			
Bridge over road (to be lowered)	1,000	0 0			
Bridge over river, with flood arches	3,000	0 0			
Culvert under Chertsey railway	500	0 0			
Occupation works	500	0 0			
			14,190	0	0
Weybridge to opposite Walton station:—					
100,000 cubic yards excavation with timbering, at 3*s.*	15,000	0 0			
2¼ miles covered channel (Section No. 5) at 4,234*l.*	9,526	10 0			
Land (to be restored)	10,000	0 0			
			34,526	10	0
Walton to Thames Ditton:					
3¼ miles fencing, one side only, at 2*s.* per yard	572	0 0			
71,280 cubic yards excavation, with timbering, at 2*s.* 6*d.*	8,910	0 0			
4½ miles covered channel (Sections 5 and 6) average 3,865*l.* per mile	17,392	0 0			
8 acres land (no severance) at 400*l.*	3,200	0 0			
Syphon under river Mole	1,000	0 0			
			31,074	0	0
			240,831	0	0
Contingencies			19,169	0	0
			260,000	0	0
Purchase of canal			20,000	0	0
			£280,000	0	0

2021. (*Mr. Prestwich.*) What you have stated has been with regard to the chalk, have you any knowledge of the delivery by springs into the canal from the Bagshot sands?—No, I have not. I have taken that as an approximation from the rainfall.

2222. Does not the canal pass through the Bagshot sands above the level of the delivery of the springs?—I should say perhaps above some, but certainly below the greater part of them.

2023. Can you tell me anyone which is above the level of the canal?—The canal at Frimley Ridge is above the level of most of the springs, but in other parts (*pointing them out on the map*) and especially where I propose to place the reservoir, it is below them.

2024. Do they all pass below the level of the canal?—The Cowshot spring passes under the canal.

2025. The canal at that point is upon a much lower level, is it not, than it is at Aldershot?—Yes.

2026. Therefore in the first long reach between Basingstoke and Aldershot you could hardly depend upon anything beyond the delivery from the chalk?—No, I do not depend upon anything else.

2027. What is the exact position of the reservoir in respect to Pirbright?—It is partly in Pirbright and partly in Woking parish.

2028. At that spot do you know what thickness of sand you have beneath the bottom of the reservoir?—No, I do not know that.

2029. Are you aware that the sands there are 100 feet thick?—I was not aware of that.

2030. (*Col. Harness.*) There is a large collection of water, is there not, between Basingstoke and Aldershot, which the railway crosses?—That is Fleet Pond.

2031. What feeds that pond?—That is fed in great part by the escape of water from the canal when it is let off from the sluices, but not entirely so.

2032. (*Mr. Prestwich.*) Might you not near Aldershot itself have a more favourable position for the construction of a reservoir for such portion of the water as would be derived from the chalk?—I am afraid not unless a new conduit were made from that reservoir down into the canal further on, because there is another reach of five miles below the Aldershot lock; and any reservoir to have any depth would necessarily be below that level.

2033. Do you know the height of the London clay in that district?—No, I do not.

2034. Does it not come very nearly to the level of the canal?—I should think it did.

2035. Those springs from the chalk I think you state you have only gauged within a comparatively recent period?—Last autumn.

2036. From your knowledge of that district do you believe that those springs maintain their permanent character for the greater part of the year?—They do not vary very much. Of all the sources which I have taken here there is only one, a small stream which yields 500,000 gallons, which I did not mention just now, that ever runs dry; all the rest are constant and remain tolerably even.

2037. I see that the total quantity that you estimate to collect at Pirbright would be equal to 14,000,000 gallons daily?—Yes.

2038. How much of that do you propose to derive from the chalk, and how much from the Bagshot sands?—12,000,000 from the chalk, and 2,000,000 from the Bagshot sands.

2039. In the 12,000,000 from the chalk you have shown that there are springs existing that would furnish that quantity, but you are not able to furnish the Commission with evidence as to the instance of any springs with respect to the additional 2,000,000 from the Bagshot sands?—The Cowshot stream which I pointed out just now is the only one that I gauged, and that I found contained 500,000 gallons, but it would appear from the map that that would only be one of several.

2040. But independently of that source you calculate upon 12,000,000 gallons?—Yes.

The witness withdrew.

GEORGE HAMMOND WHALLEY, Esq., M.P., examined.

2041. (*Chairman.*) You have turned your attention, have you not, to the question of the water supply for the metropolis?—Yes, generally to the water supply of the metropolis, and also of other towns that may require a supply of water.

2442. I understand your gathering ground would be in Wales?—Yes. My attention was called to the subject by the publication of the scheme of Mr. Bateman, for the supply of water to the metropolis. That scheme presented as a gathering ground a large district in Wales with which I am connected, as the owner of land in the neighbourhood, and I gave attention to the subject in order to see how far it would affect myself as a landowner. The result of my inquiry was that so far as withdrawing the water from the rivers of that district, it appeared to me that no persons, whatever their interest in the existing streams, need feel apprehension as to the result of Mr. Bateman's scheme, for without being enabled to express a professional opinion upon the matter, I felt I was justified in assuming, by the communications I had with Mr. Bateman, that he would be prepared to show by figures that the storing up large quantities of water, and supplying it as he proposed, could be carried out without injury to existing interests.

2043. He proposes, as you are aware, to compensate the rivers for the water which he abstracts by storing the storm waters and equalizing the flow of the rivers?—That was the point to which I directed my attention. From knowledge of that district, I felt satisfied that an enormous quantity of water could be so stored, not only without detriment to the regular flow of the rivers for mills and other purposes, but with great advantage to property in the neighbourhood of those streams by the prevention of floods. I went into the matter very fully, both by myself and also in conjunction with other landowners, and we came to the conclusion that the result of his scheme would be, with proper precautions, that while there need be no detriment to any interests now affected by the existing streams, whether fisheries, or mills, or landowners, there would be a benefit conferred upon the entire district by preventing the heavy floods to which that district is liable, and which involve landowners in annual expense, very much increasing in recent years. We attribute that increase principally to the operations of the Enclosure Commissioners and the facilities afforded to landowners for draining. Very large sums have been spent in artificial draining, and the effect of that draining appears to be to prevent the water flowing down to the reservoirs provided by nature, and from which the springs are supplied, and pouring all at once into the open channels of the country.

2044. When you speak of that district, do you mean that the district forming part of the gathering area suggested by Mr. Bateman is drained in the manner you have described?—The district to a great extent is mountain land, and no plough has ever been over it. Perhaps for a distance of say 100 miles in length, it is chiefly sheep pasture, ranging from 30 to 50 miles in breadth towards the west coast of Wales.

2045. I think you state that you have suffered from floods?—Yes, and increasingly so. The first impression throughout that country was that the effect would be to carry the rivers bodily, as it were, to London, and to create losses, and to interfere with great interests as regards fisheries, and mills, and so forth, but when we looked into the matter with more care we became satisfied that the scheme did admit of such precautions, and that Mr. Bateman seemed to be prepared to take such precautions as would obviate those difficulties, and might confer the benefits I have suggested.

2046. Have you had any meeting of proprietors in that district to discuss the effect of Mr. Bateman's scheme upon your property?—Not exactly a meeting of proprietors, but I have had more than one meeting in the town of Llanidloes, which is the first considerable town upon the river, and the town that would be immediately affected by such a scheme. We have had meetings there, and I brought my views before them to the effect now stated that it would be a benefit to the town in many respects, and those views were adopted, and the public felt disposed to do all in their power to afford a fair investigation of the scheme.

2047. You are well acquainted, are you not, with the whole of the area proposed to be dealt with by Mr. Bateman?—I know two or three parts of the area, and I think I may say I am well acquainted with it, as I have had a great deal to do with railways there.

2048. Confining your observations to the gathering area suggested by Mr. Bateman from your knowledge of that district, are you able to state to the Commission whether there are any lead or other mines, and if so, what number within that area?—There are no mines excepting lead.

2049. Are there no copper mines?—I am not aware of any. Sometimes in lead mines you find some small amount of copper, but I am not aware of any copper mines. The mines of that district are, to the best of my belief, confined to the lower portion of it, in the neighbourhood just above Llanidloes, on the slopes of Plinlimmon.

2050. Are those mines in working now?—Some of them are.

2051. Are they extensive?—They vary. It is a precarious district for working lead mines, as compared with the district further west, towards Aberystwith and in Cardiganshire.

2052. But those mines are not in this area?—No, they are not in this area of Mr. Bateman's.

2053. Have you observed the effect of the workings from those mines flowing into the rivers?—That is one of the points to which I have directed my attention. To support a scheme for the supply of water to London or other places would, of course, imply that the existing streams must be kept pure, and the owners of property containing lead would find themselves in a serious position if they were prevented, in consequence of a scheme of this kind, from working their mines. Therefore I gave attention to that subject, and the result of it was to satisfy me that there was no necessity either in the interest of the landowners or of the workers of the lead mines that the water required should be affected by such a scheme. Amongst other means that I took to satisfy my mind upon that subject, I visited a large mine worked by Messrs. John Taylor & Co., called Pant Mawr, about seven miles above Llanidloes. The washings from that mine had formerly been found to be very injurious to the fish in the river, and I called the attention of Mr. Taylor to the matter. With great liberality he gave the necessary orders, and the result of it was that the fish returned to the river, and the means he adopted was simply to increase the number of slime pits or settling pits. On a visit that I paid to those mines, I think in November last, they were working the mines, and the water was at that time running from those slime pits into the river, and within a few yards of the outfall of those slime pits small fish were to be seen in the river.

2554. Did you observe that in those pits any ingredient was used for the purpose of precipitating any of the matters held in suspension, or were the waters allowed simply to settle and pass through a series of pits?—I am not aware that there was any means adopted, except increasing the number of the pits.

2055. The water run off comparatively pure, I suppose?—Yes.

2056. You do not know whether it held anything in solution?—There were suggestions about a sulphuric element, or something of that kind; but I am not qualified to speak to that.

2057. The fish returned to a higher point than they reached before?—Yes.

T. H. Whalley, Esq., M.P.

20 March 1867.

2058. And you attribute to results of this scheme the purifying of the water from pollution?—Yes.

2059. And do you think that principle might be adopted elsewhere?—I do not see why it should not; I live in the neighbourhood of Ruabon, within a few miles of the largest lead works, I believe, in the kingdom. The largest returns of lead are yielded from the mineral district between Ruabon and Wrexham.

2060. As a landowner in the district have you yourself, or have you in connexion with other landowners, discussed the question as to this area being reserved as a gathering ground for the supply of water to the metropolis, and what the effect would be on your mineral property?—I have not so discussed the matter with other landowners, as to justify me in expressing their opinions.

2061. You have lead, have you not, on your property?—I have none worked there, but it is supposed to contain lead. There have been from time to time explorings, and so forth.

2062. If you were selling the land, you would not hesitate to state that there was just that chance of finding minerals there?—Undoubtedly it is a highly mineralized district. For instance, at one extremity of my property there are mines called Cwmystwith, and on the other side some mines called the Delife mines. Both of them are most productive mines, and have been so, especially the first mentioned, for many centuries. In the opinion of competent persons, the veins run intervening between those mines, and would run through all that property.

2063. Supposing this scheme of Mr. Bateman's were so ripened as to come before Parliament, the question for Parliament to consider would be, first, as to the gathering ground, secondly, as to the quantity of water that it would yield, and thirdly, how that gathering ground could be preserved from any source of contamination for the future, and certain prohibitory clauses might be introduced into a bill, that the owners of lands should not open mines here, there, or elsewhere, so as to pollute the streams which ultimately find their way into those reservoirs. What would be your view of such a piece of legislation; would you still think that Mr. Bateman could be a great benefactor to the district by carrying out his scheme, or would you think it an interference with the rights of property?—Putting it in that way, it would materially interfere with the rights of property; but I am acting upon the assumption that having regard to the importance of the public demand for water, there would be means adopted to afford protection to the landowners for such interest as might be unavoidably interfered with.

2064. But would you as a landowner be prepared to submit to prohibitory clauses restricting the exercise of your rights over the property, and requiring that you should not open a mine at point A. B. or C., because the result of that working might contaminate the water?—I should not, in the state of my present information, be prepared to submit to such a clause, nor should I think such a clause necessary, because in a case in which I had occasion last year to obtain a bill for the supply of a small district in my own neighbourhood, the water which came from my own land, and from a district which is not only mineralized by lead works but also by coal and ironstone, I consulted my solicitor with regard to the protection necessary, and he told me that the General Water Clauses Act would afford sufficient protection. I am not assuming that landowners would consent to be deprived of any powers that they now possess over their land; I merely express an opinion that it being put upon the principle that they were not to be injured, either they would not be injured, or if they were injured they would only be injured to so moderate a degree as that a scheme of this kind would provide the means of compensating them.

2065. Do you think that Parliament would consent to an expenditure of 10,000,000*l.* or 12,000,000*l.* to carry out those large works, the object of which would be to convey to London the water gathered from that district, without at the same time protecting that water from pollution by prohibiting certain things?—I have never considered it in that way, because I do not think that Parliament will sanction such a scheme as Mr. Bateman's, and if my plan is adopted I do not think it necessary that they should do so.

2066. You are aware that one of the propositions that is placed before the Commission is to gather the water in that district and so bring it to London?—I had an interview with Mr. Bateman, and suggested to him that instead of involving the country and the metropolis in the expense which he proposed, and the delay which must take place in accomplishing his object, he might adapt his scheme somewhat in this way, to afford facilities to the landowners who might happen to have water rising in or flowing through their lands, and also lands readily convertible into reservoirs to make such reservoirs; also to afford facilities to the railway companies which now penetrate that district to convey that water from those reservoirs by pipes along the course of the railway, thus obviating the necessity of great engineering works and so forth, and also to afford facilities for existing water companies either in the metropolis or elsewhere to purchase the water so conveyed. I subsequently ascertained that such facilities would be, I think, eagerly seized by landowners in that and other districts with a large extent of mountains and with a most perfect water. I also found by communication with the Great Western Railway Company, and at the time being chairman myself of railways in the district, that we should be most happy to convey the water, I think I may almost say for nothing, in consideration of the great advantage which the railway companies would derive from having the command of water of such extreme purity and softness for the use of their engines; of itself a very great advantage and saving in many cases to the railways. I found that the London and North-western Railway Company had already carried out between Crewe and some districts in that part of the country something like the scheme that I am now suggesting; that is to say, storing water and conveying it along their line for the use of their engines.

2067. I suppose it was to be carried by means of iron pipes?—Yes; I also found by communication with a gentleman recently returned from India, that a scheme of that kind had been carried out with extraordinary success for carrying water a distance of 50 miles to Bombay by a pipe from five to six feet in diameter, along the railway, and that the effect of that had exceeded everybody's expectation; it had diminished the deaths in Bombay by something like one-third. He had no doubt, nor in fact have I heard any doubt expressed by the persons connected with railways who have had any means of forming an opinion that there would be any practical difficulty in conveying along the railways the water that might be so stored up in the way I have suggested. As this would be done by the landowners, for their own benefit as a means of making the most of the resources of their property, they would take care that the water was kept pure and thus meet many of the difficulties now suggested of that nature.

2068. Then I understand your proposition to be this, that the landowners in the district should have the control of their own water, that they should gather from their own ground, or unite together for the purpose of gathering from a large area water in one reservoir, and become wholesale dealers in water, supplying any company that might bring up their pipes to the place where you have gathered your water?—Yes; that expresses my views quite accurately.

2069. You state that you had some communication with the Great Western Railway Company; was it with a director or with the chairman?—No; with Mr. Grierson, the manager. I have not been in a position to ask him for an authoritative opinion, but I stated that I was obtaining information for the purpose of bringing it before a public meeting in

Llanidloes, and consulted him whether he could suggest any practical difficulty in carrying out such a scheme, and his reply was that he could not, but on the contrary, it appeared to him a feasible mode of conveying water by means of pipes along railways; either one pipe or many pipes; and he referred to the fact that there was a scheme before Parliament some few years ago for bringing salt water from Brighton to London for bathing purposes, and that it passed so far as any engineering or railway difficulties were concerned, and that there was no practical objection suggested to it.

2070. (*Mr. Harrison.*) One object would be to deliver the water in London at such a height that there might be a constant high level service. If your idea is carried out that you are to convey it through pipes there is no doubt that the fall per mile in the pipes would be a great deal more than you would require for carrying it in a mere open conduit, and, in fact, if there was any great extent of pipes to be used in the length of it it would do away with that object which is the essential one to be obtained?—That is an engineering question. I had some discussion with Mr. Bateman upon the subject at the Social Science Congress at Manchester, and I think that that was his difficulty. I urged upon Mr. Bateman the abandonment of his scheme in favour of free trade in the supply of water or that he should proceed with his scheme at once. His reply was that in the first place he was too much engaged to give attention to the matter for this present session, and in the next place he suggested the difficulty which you have now pointed out, that he could not by means of pipes along the railway maintain the requisite elevation.

2071. If you were going to carry it by pipes all the way, you could not by possibility bring it to London at a high level, you must have a greater fall through the pipes than by carrying it in conduits?—That is a matter upon which an engineer would speak better than I can. You are aware that Llanidloes is the highest corporate town in the kingdom. I consulted various towns on the route; the towns of Builth and other small towns that are in very great want of water, and I found that the laying of pipes of this kind along the railway would be found highly remunerative in the supply of water to all those intermediate places, and that they would be enabled to pay a considerable sum for the water which could be so supplied to them, rather than be subjected to the expense which many of them are contemplating of constructing independent reservoirs; that, in fact, the railway would be one continuous reservoir for every town and every kind of works, including the railway company's service.

2072. Are you aware that the cost of conveying it by pipes per mile would be largely in excess of what it would be to carry it in an open conduit?—Of course I must leave that question entirely to the engineers; but it does not follow that all the water must be brought by one route, as in the case of an open conduit, such as Mr. Bateman's, one railway will bring one supply and others the like.

2073. (*Chairman.*) Pipes would be a necessity, would they not, if it were brought by rail?—Yes.

2074. (*Mr. Harrison.*) It would be infinitely more expensive, would it not, than the plan proposed by Mr. Bateman, of bringing it partially in conduits and partly by pipes?—I can hardly imagine that. It has been done frequently in other cases. I can mention a case where it has been done at Tenby, to which the water is brought from near Pembroke.

2075. There they have got an abundant fall, have they not, and a head of water which enables them to use a much smaller pipe?—I am not aware of all the circumstances of that case.

2076. You are pretty well acquainted with the Vale of Llangollen, are you not?—Yes.

2077. Taking the Bala Lake and the whole of the district there, I suppose you look upon that as one of the finest supplies in the whole of North Wales?—Yes, Bala Lake is just an illustration. It happens to be a natural lake, but I believe that anybody who went over this district from Bala Lake would find in plots of 50 100, 200, and 500 acres of land that might be converted into lakes similar to Bala Lake, and at a comparatively trifling expenditure with thousands of acres of gathering ground around them which has never had a plough upon it, and seems exactly adapted by nature for the purposes of a gathering ground.

2078. (*Chairman.*) Have you formed any opinion in your own mind as to the price at which landowners would be prepared to sell their water?—No, in the instance that I referred to of supplying water to a district in the parish of Ruabon, that question was put to me. I referred the matter to competent persons, at Liverpool—engineers and other persons—and the result has been, that they agreed to pay a royalty to me of one-tenth of the gross receipts that the company will receive from the supply of water. That was settled in that instance, and, I believe with general approval.

2079. You are aware, are you not, that you have no interest in the water beyond what is due to the supply of your estate; that is to say, if you intercept water which has from all time run into a certain channel either utilised for mill purposes or otherwise, any interception on your part would involve compensation to the parties below you?—Of course.

2080. If you catch water because water falls upon that area it does not follow that you have any vested interest in that water and that you should deprive others of their natural rights?—No; but that is a different state of things to conferring upon other persons a vested interest in the surface of the land, for instance, laying pipes, or storing and so forth, it is giving a service over the land, which may prevent buildings and many things to which the land might be applied.

2081. I think your suggestion might be taken generally to be quite at variance with the principle which is adopted by water companies generally; their plan always is to buy the fee simple of the land upon which their reservoirs are placed. I am not aware of any case excepting the one you mention in which what may be called a royalty for water has been paid?—In this case the option was given to the company either to pay it in that way or to pay at once 1,000*l.* for the land, which included several acres of land.

2082. (*Sir B. Phillips.*) Did I understand you at starting to say that as far as Mr. Bateman's scheme was concerned, you thought it would be very beneficial to the landowners in your district for the purpose of preventing constant floods?—I think if carried out as proposed, it would be so; that is my opinion.

2083. Then as far as that goes you approve of Mr. Bateman's scheme?—Certainly.

2084. Then you subsequently say, do you not, that as far as the public is concerned you disapprove of it?—As far as the delay and the cost were concerned, great objections occurred to me.

2085. Of course it could not be carried out without delay and cost?—By the scheme that I suggest you might have a supply from those mountains in six months. I should suppose it would be very easy to lay a pipe the whole distance and at very much less cost than Mr. Bateman's scheme.

2086. (*Chairman.*) What I understood you to say was this: that Mr. Bateman proposes to abstract from the rivers a certain amount of water, and to compensate for the river water so abstracted by reservoirs storing the storm water, and thus not to injure the rights of the millowners on the stream or any parties having rights below the point of abstraction?—Certainly.

2087. And then, with regard to your own scheme, you have stated that is just what we landowners could carry out; we could make our arrangements; we could construct those reservoirs; we could store a sufficient quantity of water to compensate those rivers for what water we are taking, and we should, therefore, not be liable to compensation to millowners, and we should constitute ourselves large wholesale dealers in water, and be prepared to supply

T. H. Whalley, Esq., M.P.
9 March 1867.

any company that will bring their pipes up to our ponds?—Yes.

2088. (*Col. Harness.*) Do you believe that you could carry that out without an Act of Parliament?—In the first place, without an Act of Parliament you cannot protect yourselves against the polluting of the water above, and, in the next place, you are left entirely at the mercy of millowners or anybody else who may be on the stream below. Again, landowners cannot, as a general rule, find ready money to carry out those schemes. Parliament has already interfered to assist landowners to make the most of their estates by means of draining and fencing, and so on, giving to those who may be interested in the reversion, or the mortgagees, such protection as can be given by an examination by the Enclosure Commissioners, and a certificate that the expenditure will be a permanent benefit to the estate, so that the reversioners will not be injured. I think it reasonable that the same principle upon which that has been allowed, and is daily practised with regard to drainage should be extended to developing estates with regard to storing up water.

2089. (*Colonel Harness.*) That point would of course only be applicable in case you require to borrow public money for the purpose?—Yes, of course. You can either borrow public money, or you can advance money as it were to yourself; that is to say, the money that is so spent might take precedence over all previous charges, such as mortgages and reversions and so on. Then the next point that you would require is, that a landowner who should go to the expense either by borrowed money or by his own money to enclose say 100 acres of land for a reservoir or to make a Bala Lake or something of that kind, should be enabled to protect that lake against the water being polluted above. Then a third matter, and one of very great importance, is that there should be some means of readily ascertaining the amount of compensation to be given to millowners and other persons who may apprehend damage below. For instance, in the case I referred to in Ruabon for many years past an impediment to carrying out a scheme of that kind has been a tumble-down good-for-nothing old mill, which was on the lower part of the stream. No power could get this man to agree to any terms; we had no means of ascertaining his loss, he would not tell us; he would not take any reasonable compensation, and, in fact, there was no dealing with him. A clause has been introduced by Lord Redesdale whereby we agreed to provide him with the same quantity of water out of our storage as he has at the present time for his mill, and that the mill should not be in greater want of water after those works are carried out than they were before, with the option of paying him for all his rights the sum of 450*l.* That, practically, was the way that we dealt with him. Then, according to my plan, if we spend 5,000*l.* in enclosing the land and making a lake that 5,000*l.* will so add to the value of the estate that persons would be found willing to advance money upon it.

2090. (*Chairman.*) There is no doubt, I think, that you require statutory power for that purpose?—Yes, that would be so. The bill which I sent to the honourable chairman explains exactly what I propose.

2091. (*Mr. Prestwich.*) Does cultivation extend much in the area marked on the map as the drainage of Mr. Bateman?—Very little; it is almost entirely mountain; and I should think it is quite a fractional part just down in the valleys.

2092. You stated, did you not, that the floods were increasing from year to year in consequence of the improved system of drainage?—Yes, in the lower part of those valleys.

2093. It is, therefore, within a portion of Mr. Bateman's area that your observations would apply?—Yes, certainly.

2094. (*Chairman.*) Do you know if there is any considerable portion of that area under high cultivation?—No, not at all a considerable portion. I should say that certainly one-tenth of it is not cultivated at all. Nine parts out of ten are mountain sheep walks.

2095. (*Mr. Prestwich.*) Is that cultivation extending at all on the sides of the valleys?—Not recently, because the sheep have been increasing in value.

2096. (*Chairman.*) The water would be an unexpected mine of wealth to the landed proprietors?—Yes, that is the way in which I put it.

The witness withdrew.

Adjourned to to-morrow at 11 o'clock.

Thursday, 21st March 1867.

PRESENT:

SIR JOHN THWAITES IN THE CHAIR.

Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

T. Duncan, Esq.
1 March 1867.

THOMAS DUNCAN, Esq., examined.

2097. (*Chairman.*) Are you a civil engineer?—I am.

2098. Are you engineer to the Liverpool Waterworks?—I am.

2099. Are those works under the municipal authority of Liverpool?—They are.

2100. Have you been long engineer to that corporation?—I have been over 23 years engaged in the Liverpool Waterworks, and for the last 16 years I have had the entire charge of the home works, and more recently I have been engineer in chief of the whole of the works.

2101. You are supplied at present from what district?—We are supplied from two sources, one a catchment, and the other from wells; we draw a considerable quantity of water from the wells out of the new red sandstone in the neighbourhood of Liverpool, and the other portion from Rivington. You will observe on the map the district of Rivington, and the black dotted line shows the pipe line down to Liverpool.

2102. Is that the main source of supply?—Yes, that is the main source of supply.

2103. What is that district coloured higher up?—That is the Hodder district. In the investigation which I was requested to make for extending the supplies to Liverpool I had occasion to examine this district.

2104. That forms no part of your present source of supply?—No.

2105. Is that which you have pointed to as the present source of supply found equal to the requirements of Liverpool?—No, it is very deficient indeed.

2106. What was the anticipated quantity of water which you expected from that area?—16,000,000 gallons a day for the use of Liverpool was Mr. Hawksley's calculation, based upon a mean rainfall of 48 inches, but we have fallen very much below that.

2107. Do you remember what Mr. Hawksley's calculations were as to the quantity of water that would run off after allowing for absorption and

evaporation ?—75 per cent. ; he took off a quarter, and then he allowed one-third of the remainder for compensation to millowners and others having water rights on the streams which we take.

2108. Still he calculates so much water ?—Yes.

2109. 36 inches out of the 48 would be available either for the supply of Liverpool or the compensation of rivers ?—Yes, and he gave off one-third.

2110. What has been your experience with regard to that area as to the rainfall for the supply of Liverpool ?—If you will allow me I will hand to the Commission copies of my reports, the one is a report referring to the catchment scheme, and the other is a report referring to the present source of supply and also to another project which I brought before the Corporation of Liverpool. (*The witness handed in the same.*)

2111. What is the area of your present gathering ground ?—10,000 acres.

2112. Mr. Hawksley calculated that out of the mean average of 48 inches he would have available either for the supply of Liverpool or compensating the rivers 36 inches ; what has been the result of the practical working ?—It has fallen very much below that ; the mean rainfall of the district itself has been very much below that. If you will have the kindness to turn to Appendix C. in the report of July 1866 you will find it stated that the mean of 17 years was 45·70.

2113. That is 2¼ inches less than Mr. Hawksley calculated ?—It is, but as you will observe the minimum is very much below that, and it is in the years of minimum rainfall where the difficulty is experienced.

2114. You therefore have now a mean fall of 45·70 ; do you find that you realize 75 per cent. of 45·70 ?—If you will turn to Table D. you will find another table which will give you the result.

2115. That table shows that in 1865 it was 67·12 per cent. of the rainfall ?—Yes, and in 1862 it was 82.63.

2116. That gives a mean of 75·61 ?—Yes.

2117. So that that would seem to confirm Mr. Hawksley's view ?—Mr. Hawksley's calculations, taking the rainfall as he was then from the best information which he could obtain able to determine, were right, but unfortunately it has been found that we have had some years when we have not had anything like the quantity off the ground that he estimated as you will observe.

2118. We want first to ascertain whether the general principle laid down by Mr. Hawksley has been realized in practice ; it is another question as to whether the minimum fall would be equal to your requirements. Can you point to any year or years in which the rainfall has been very much less, and what has been the inconvenience which you have experienced ?—In the year 1865 we had 34·80 inches of rainfall. From my observations during that year, the per-centage of rain impounded was 67·12 per cent, which was very much below the 75·61, and that from a much smaller rainfall, of course, gave a very much smaller quantity of water for the ground. During that year the average daily quantity impounded, as you will find in the fourth column from the left hand of the table, was 14,476,865 gallons per day. We suffered great privations in Liverpool during that year, inasmuch as while we were only receiving for Liverpool from the catchment 6,176,865 gallons, after having given off 8,300,000 gallons as compensation which we were obliged to do by the Act, we gave away as compensation a larger quantity by about 2,000,000 gallons than we received for ourselves. (*The witness handed in a diagram. See Appendix R.*)

2119. You were under statutory obligation to compensate the rivers to that amount ?—Yes, we were.

2120. If I understand rightly, in the year 1865 you received eight per cent. less from that gathering area than the amount calculated by Mr. Hawksley?—We did.

2121. Was that eight per cent. due to the diminished rainfall or was it due partly to the absorption and evaporation arising from the condition of the ground ? —Both causes must be taken in connexion with each other. During the year when you have a minimum rainfall the showers come very lightly, and although they may count in a gauge, they do not in the streams. The rain is evaporated in many instances as fast as it falls, it neither reaches the ground to sink into it to come out in springs below, nor does it come off the ground into the rivers ; it is not in sufficient quantity. From my observations slight showers do very little good indeed to the impounding of water. It will vary very much as the nature of the surface of the ground varies. If you have a very steep descent and a very retentive subsoil or rocks that are not easily permeated by water, you will get a larger quantity down, but if you have a flattish country and an absorbent rocky or gravelly soil, you will get a smaller quantity. Hence, in a year when you have a succession of light rains you do not receive the benefit, and that accounts in my mind for the discrepancy in the per-centages which have been obtained.

2122. Is not that to be accounted for by the condition of the ground, its heat, its dryness, and its power to absorb as well as by the evaporation ?—Certainly.

2123. (*Mr. Harrison.*) Looking first at your second column and then at your sixth column, you do not appear in any one year to have had a loss of as much as 12 inches. That is to say, in 1861 the rainfall was 46·38 inches, and then, taking the proportion which is what you realize at 35·77, that is slightly under 11 inches. If you take the next year as 48·51 against 40·08 that is a loss of 8 inches. In the next year it is 51·01 against 40·72, that is under 11 inches again. In the next year it is 39·035 against 27·85, which is the only year in which the loss is over 11 inches ; and in the next year it is 34·80 against 23·35, making a loss of 11½ inches. Therefore, whatever your rainfall be, whether it be large or small, the actual loss would seem to be very nearly the same ?—The amount of evaporation and absorption does not vary much.

2124. (*Colonel Harness.*) Which would your experience lead you to prefer, a proportion of rainfall to be deducted or a definite quantity to be deducted ?—I should prefer a definite quantity if I could so arrange it and I would do it in this way. In a given area where the waters were collected into one reservoir, I would give out as compensation a proportion equal to what I drew off for use elsewhere. But to say that you will fix a given quantity upon a mean of years I think is fallacious, and it is shown to be so from my experience at all events. For as I pointed out just now, when we were giving off what was a fair quantity calculated upon a third of the water which found its way into the reservoirs in the mean of years, we were only receiving for Liverpool 6,000,000 gallons, while we were giving off 8,000,000.

2125. My question alluded to the estimated loss by evaporation and not to compensation to the streams. Which would you prefer in making a fresh estimate, to estimate the loss by evaporation on a proportion of the rainfall or on a definite quantity ?—You may take the proportion of the rainfall as very nearly correct, taking it in connexion with the physical character of the district over which you collect your water, it is then a matter of opinion which mode you would adopt. If you take the same basis in each case it is of very little consequence how you give it off, if I understand your question correctly.

2126. It seemed a question whether the quantity of between 11 and 12 inches lost by evaporation was not nearly constant, although the quantity of rainfall varied. Would you in future, in making such estimates, prefer to take a definite quantity of say 11 or 12 inches ?—Yes, I would be inclined to do so if it were based upon observations extending over a sufficient number of years.

2127. (*Mr. Harrison.*) Let me call your attention to Table D. again. It appears that Mr. Hawksley originally calculated upon a mean rainfall of 48 inches. In 1862 you appear to have had for the consumption of mills 8,300,000 gallons, and left for the town or run to waste 16,544,000 gallons ?—That is so.

2128. That is really exactly corresponding in that case with Mr. Hawksley's calculation of one-third for the mills and two-thirds available for the town ?—Yes.

T. Duncan, Esq.

21 March 1867.

2129. But when you come down in 1865 to 34 inches the 8,300,000 gallons is still a constant quantity and reduces what you have for your town supply to a less amount than you really have to supply the mills?—That is so.

2130. Therefore it is hardly perhaps correct in taking this as a basis for calculation that you should take one-third for consumption in order to make the calculation valid, it would seem that you ought to assume a fixed quantity for the mills?—Yes, it ought to be upon the minimum rainfall. I think that calculations for the supply of towns should be upon minimums and not means, and I think there is a note in my report to that effect. That is the conclusion to which I have arrived by observation.

2131. In point of fact, unless you take the minimum or unless your storage will carry you over 12 or 18 months, you are quite sure to be deficient?—Yes; in wet weather the millers get the advantage, and in dry weather they have a very much larger quantity than they would have received had they been depending entirely upon the natural flow of the rivers.

2132. (*Chairman.*) Therefore your principle of compensation has rather given a regularity of power to the millowners than that which they previously enjoyed, that is to say, in the case of drought, there would be no such thing as drought in the river under the present arrangement?—No; the river would be kept, exceping in time of floods when you could not retain the waters, at one equal flow.

2133. A flood itself would be no advantage to the millowner except as giving him the power of impounding the flood water to the extent of his capacity?—To a miller who had adjusted his machinery to the ordinary flow of the river, it would be very little or no advantage, but it would be a great advantage to the river to have a flood now and then.

2134. But taking the millowners, and looking simply to their interests, are you of opinion, having regard to your experience, that they are under as favourable conditions now as they were before this arrangement was come to?—Yes, far better. They can now depend upon what they have to get, whereas formerly they trusted entirely to floods.

2135. Before this arrangement was come to in very droughty weather the river must have been in a condition that they could not work their mills?—Yes.

2136. Whereas now they have a constant supply?—Yes. Taking our own case, the Leeds and Liverpool canal, which receives water from us, given out at one point, about 3,000,000 gallons of water a day which flows constantly. I have seen the stream before the works were constructed when there was not more than one-third part of that quantity flowing down, now they have it constantly, and they have the first draw.

2137. I understand from your answer that the original calculation made by Mr. Hawksley has, in point of fact, been confirmed, and you only differ from him in accepting the minimum fall instead of the mean?—Yes.

2138. What is the general character of the area from which you take your supply; is it cultivated at all?—Partly; I should say that five sixths of the land is moor and sheep pasture land covered with heath, and some portions of it mossy, the geological formation being millstone grit chiefly.

2139. Is any part of it under cultivation?—A very small portion of it is ever ploughed; I should say not one-fiftieth.

2140. Can you trace any pollution of the water to that cause?—No, I think not; I think it is scarcely appreciable, the ratio is so small in comparison.

2141. (*Sir B. Phillips.*) What is the quality of the water?—It is very good; it is under three degrees in hardness. I can hand in to the Commission, if they desire it, a copy of Professor Way's analysis of the reservoir water, and samples of the river waters.

2142. (*Chairman.*) I understand that the question of an increased supply to Liverpool has been under the consideration of the corporation?—It has.

2143. And you have been directed, have you not, to report to the corporation upon that subject?—I have.

2144. And are the reports which you have handed in founded upon that investigation?—Yes, those are the reports which I have handed in.

2145. To what source have you directed your attention for an increased supply?—I have looked first of all to the source of the Hodder, and I have considered the river Ribble and the lakes; first of all there is Windermere Lake.

2146. There is a part of the coloured watershed, amounting to 43,315 acres above your present supply, intervening between Preston and Lancaster, and the east; what does that refer to?—That is simply the drainage area of the river Hodder down to its junction with the Ribble—43,315 acres.

2147. That 43,315 acres is represented by that portion coloured yellow on the map?—Yes.

2148. Then there are two other watersheds?—Yes, the one 5,000 and the other 13,000 acres; those are the portions which I assume we would be able to impound.

2149. Therefore it would be a little over 60,000 acres?—Yes, I think so.

2150. What do you calculate would be the yield of that district?—Very much like the Liverpool district.

2151. It is six times the area, is it not?—Yes, but it would be in the same ratio; I take the rainfall of this district as very much like that which we find at Rivington.

2152. Is the geological formation much the same?—The lower part of the valley is chiefly lime; the upper portions are partly millstone grit and partly lime.

2153. Then you would have hard water?—Yes, unless by going well up, and that is the reason why I have assumed that the upper waters of the Hodder should be taken; I had two objects in view, the one to get sufficient altitude and the other to get better water, as there would be very little limestone area in it.

2154. I presume that you could convey the water that you have occasion for from this district to Liverpool?—I could.

2155. What head does that give you?—It is an an average fall of 3 feet per mile as far as the Rivington works.

2156. Have you any pumping?—There would be no pumping there.

2157. At what height are you above high water at the Liverpool Waterworks?—I would explain that the project for this portion was examined with the view to deliver the water into the Anglezark reservoir, and so send it down by our system of pipes to Liverpool; I was required to consider this because it had been thought by several parties that this was a favourable place to go to to look for water; and it was suggested that it could be taken into our Liverpool system and made a part of it.

2158. If I rightly understand the colouring of this map you bring your water from that area, and utilize your present tunnel or aqueduct?—The suggestion was that we should utilize the present works.

2159. Is that aqueduct of sufficient capacity for the increased supply?—No, certainly not.

2160. How do you propose to deal with it?—A new line of pipes would require to be laid.

2161. What size are your present pipes?—Our present pipes are 44 inches in diameter; in point of fact it would be wholly a new work.

2162. How many have you?—Only one up to Prescot, which is eight miles from the Exchange, and from Prescot into Old Swan, where we divide the water, which is $3\frac{1}{2}$ miles from the exchange, I have two lines of pipes, one 44 inches and another 36; the 36-inch pipe has only been in use for a year and a half.

2163. Then, in fact, you would supplement your pipe arrangements?—Yes.

2164. They are all iron pipes I suppose?—Yes,

excepting about three quarters of a mile of tunnel coming through the summit near Rivington.

2165. Then the water from your new source of supply would also be conveyed in iron pipes?—Yes, excepting the upper portion for some distance along the line which you see marked red from the proposed watershed coloured green and pink; a considerable portion of that 10 miles might be in tunnel or culvert formed along the contours. Then passing the valley of the Ribble we should have to use pipes, and we should use pipes beyond that for the greatest portion of the way.

2166. Why have you elected to use pipes instead of an open culvert or tunnel?—In passing through a valley, unless you can get ground suitable, you cannot work under a pressure in the open, whereas you can do so with pipes.

2167. You have a great number of syphons, I suppose?—Yes.

2168. (*Mr. Harrison.*) Do you filter the water at all?—Yes, we filter all our Rivington water.

2169. (*Chairman.*) Is that found necessary?—Yes, absolutely necessary.

2170. I presume that that is done in order to free it from anything held in mechanical suspension?—Yes, all that is held in suspension is taken out by the filter; we cannot get rid of the colour, though we take out a portion of it.

2171. Have you any peat in your district?—Referring to the suggested Hodder district, there is a little at the very top of the hills, but the higher we go up this stream we find the water becoming more brown until it is mixed with the whiter waters which come off the limestone below. The upper waters come off the millstone grit. The water of the greatest altitude is the softest water, although it is more highly coloured than the lower waters.

2172. Have you any peat in the area of your present supply?—We have.

2173. How do you get rid of the discolouration?—By filtration.

2174. Will filtration accomplish it?—To some extent, we use filtration alone. We use nothing else but an ordinary sand and gravel filter. We find there is as little colour left in it as there is in nearly all mountain waters, and probably a little more at one time than another.

2175. What was the character of the water supplied to Liverpool prior to the present supply?—It was derived from wells sunk in the red sandstone.

2176. Do you remember the properties of that water; was it hard?—Generally hard. One or two wells were better than the rest. With regard to the Green Lane well for instance, which is the best of all the waters, when first we got water there, we had an analysis made, and it was about 4½ degrees of hardness; it is now about 7. I have not had it analysed very recently; about 7 is the correct degree. The other wells in the town were very much harder. I can hand in a table of the analysis of those waters if the Commission wish it.

2177. (*Sir. B. Phillips.*) Do you continue to use the waters from those sources?—We are using the water from Green Lane, Windsor, Dudlow Lane, Bootle, and Water Street.

2178. Are those all the sources from whence your water was supplied before the construction of the Rivington Pike scheme?—No, we had several other wells; we had Hotham Street, and the Bush and the Soho Street stations.

2179. What quantity of water per day used you to receive from those various wells?—35,000,000 gallons per week. From the old sources the greatest quantity we ever raised from all the wells together was somewhere about 42,000,000 to 43,000,000 gallons per week.

2180. Have you discontinued the use of a certain portion of those wells?—Yes.

2181. Do you know how much water you receive from those portions which you continue?—Yes.

2182. How much do you receive from those sources now?—Generally about 38,000,000 or 39,000,000 gallons; it varies occasionally.

2183. (*Chairman.*) Your object in seeking this fresh source of supply or the result of it would probably be to discontinue the supply from those wells?—Yes, no doubt.

2184. Then the water from some of those wells was of very much greater hardness than the water from one or two wells which you say was something like seven degrees of hardness?—It varied considerably.

2185. Have you observed in Liverpool, or has your medical officer reported to the Corporation, the effect of this soft water which you have been using for some years past as compared with the use of hard water previously?—I had occasion to receive a communication from our medical officer during the autumn of last year, when I was requested, if possible, to give a larger quantity of the hard water into a district of the town than I was giving. No doubt he had good reasons for asking me to do so. I did not quite understand him; I had always been given to understand that the softer and purer the water the better.

2186. Did he ask you specially to supply the hard water, or did he ask you for an additional supply of water, knowing you were limited elsewhere?—This requires a little explanation. We have several reservoirs at home in the neighbourhood of Liverpool into which we receive the water from Rivington and also the pumped-up water from the wells in the district, there was very great difficulty, in consequence of the structure of our mains, in getting such a quantity of well water or Rivington water, as the case might be into one reservoir as there was in another; and what the medical officer wanted, after having made an examination of some districts of the town, was to equalize the quality of the waters, and that equalization was to be brought about by getting a larger quantity of well water into a district which was getting a softer water than the others. I made some arrangements; they complied with his request, so that now the quality of the waters throughout the whole district is very nearly alike.

2187. Did he ask for that water on account of its hardness?—I believe it was on account of its hardness. If you will permit me I will hand in the letter which the medical officer sent to me. (*The witness handed in the following letter*):

"Public Offices, 2 Cornwallis Street,
"Medical Officer of Health's Department,
"Dear Sir, Liverpool, June 16, 1866.

"In obedience to a resolution of the Mortality Sub-committee, I herewith forward to you a copy of Dr. Sheridan Muspratt's analysis of three samples of the service waters of Liverpool taken from the main pipes situated in the northern, southern, and central districts of the town.

"There are, in the results of this analysis, some points of hygienic interest, which, having attracted the attention of the Committee, I beg also to bring before your notice. The first is the difference in the quality and in the saline or foreign constituents of these waters. This is as great as what will generally be found to exist between those of towns placed several miles apart, and in geological formations of very dissimilar character. Now, though variety in food is a cardinal axiom of dietetics, yet, in the case of drinking water, it is found that the slightest change from what the stomach has been accustomed will in delicate persons occasion dyspepsia and visceral derangement. Indeed, I can readily conceive, that a weakly person used to the hard water of Toxteth Park will be very disagreeably inconvenienced by drinking the soft water of Hornby Street, and *vice versâ*. It is desirable, therefore, on general health principles, that, if possible, the water supplied to the whole borough should be homogeneous and the same in quality at all times and all seasons.

"The next point to which the Committee's attention was called was the amount of the nitrates and of organic matter in the several waters. It is presumed that none of the samples were either pure "well water" or unmixed Rivington water, but that the latter predominated in the Hornby Street sample, the former in that of Mann Street. Now, taking the amount of nitrogen in the 0·6361 of a grain of the nitrate magnesia to represent 0·2 of organic matter, we have 0·900 or nearly one grain of organic matter in the water of Hornby Street. This is pretty much what was found by

T. Duncan, Esq.

1 March 1867.

Dr. Lyon Playfair in 1847 to exist in the stream below Anderton Ford, and, therefore, it is so far satisfactory to know that the waters of the lake have not been materially, if at all, deteriorated by being impounded from a large area of ground.

"You will probably remember the purport of Dr. Fairplay's conclusion which, to use his own words, was: "Organic matter is never to be desired in water, but in the "present case (Rivington streams) it is present in very "small proportions, so small as to be wholly innocuous." I do not venture to differ in opinion with this high authority, but still I think that if by a more liberal mixture of well water you could not only bring the Hornby Street water to be on a par with that of Abercromby Square, but also lessen proportionally the quantity of its organic matter, it would be desirable to do so.

"In the case of the Mann Street supply, a skilful admixture of the Rivington water would lessen the amount of saline ingredients and make it, if not more wholesome, at least more useful in household economy. At the same time it must be admitted in the favour of our present system that 19 grains to the gallon is less than what used to be found in the water supplied by the Bootle Company or the Liverpool and Harrington Company.

"In conclusion, I think I give expression to the opinion of the Mortality Committee by stating:

"1stly, That it is desirable, if possible, that the water supplied to the borough should be homogeneous, and that to secure this being the case at all times and all seasons an analysis of the waters supplied to the several districts should be published at stated periods.

"2ndly, That in attaining this homogeneity in quality an endeavour should be made to bring all the water of the borough to the purity of that now supplied in Abercromby Square.

"I remain, &c.

"Thomas Duncan, Esq., W. TRENCH."
Water Engineer."

2188. With regard to the change from one water to the other, have you any evidence to show that it has had a beneficial effect upon the human system?—I know that washerwomen and brewers grumble at the hardness of the water. I have frequent complaints of the water being very hard in the districts; for instance, at the very last committee that we had at Liverpool several complaints were made of the hardness of the water. We were getting from our new works a rather larger quantity of hard water than was liked for most purposes; although the well water is preferred for drinking, for all other purposes the softer water is preferred.

2189. Had you any report from your medical officer upon that subject?—I had no report from him.

2190. How long has the present system of supply been in operation; I mean other than from the wells?—The mixed water has been supplied to Liverpool a little over 10 years.

2191. Has the medical officer made any report during those 10 years with regard to the improved health of the town, and has he attributed it to the change of water?—He has made several reports, but I am not provided with them; he has made a number of reports upon the sanitary condition of Liverpool, but I do not remember them just now.

2192. Can you give this Commission some evidence as to the advantage of the soft water over the hard water for manufacturing and other purposes?—Brewers like the soft water better; they get a better extract, and can make a better beer, and distillers like to use it for breaking down spirits.

2193. Can the brewers make the light bitter beers from the water?—I do not know that Liverpool is very celebrated for its beers, but they like Rivington water much better than they do the well water.

2194. You mean for making porter?—No, they make a comparatively light beer; I have had many complaints of giving them hard water. When I have been obliged, from some cause which I could not prevent, to give them a larger quantity of hard water than they have been accustomed to, they have complained very bitterly.

2195. Do you find that they detect the presence of hard water without any notice being given to them?—Yes; this may be partly owing to treating the one water the same as they would the other without having been warned; a part is due to that, but the most part is due to the water itself.

2196. For general manufacturing purposes, such as dyeing and scouring, is soft water better?—There is no doubt about it that soft water is better.

2197. (*Sir B. Phillips.*) You have but very few manufacturing interests in Liverpool, I think?—We have a good deal, but not stuffs; we sell about 1,500,000 gallons per day for trade purposes in Liverpool; there are no dye-works, or only very small ones.

2198. I understand you to say that you derived from the well sources originally something like 35,000,000 gallons per week, gradually increasing up to 43,000,000?—Yes, that was the maximum.

2199. Certain portions of those wells you continue still for the supply of the town?—Yes, we do.

2200. Can you tell me up to your last year what quantity was drawn from the well sources?—We have it, for instance take November 1866, the quantity was 40,000,000; 39,000,000; 39,000,000; 39,000,000; 39,000,000; 40,000,000; 37,000,000; 35,000,000; 35,000,000; 40,000,000, and so on.

2201–2. So that you really retain as large a supply now from your old sources as you took from them before?—We do as a whole, but not from the particular sources. We abandoned in 1858 some of our wells, and we have increased the quantity since then from the others.

2203. How many wells have you altogether in number?—First of all we had the Bush, Soho, Water Street, Hotham Street, Windsor, Green Lane, and Bootle; we had seven wells.

2204. How many have you abandoned?—We have abandoned three—Soho, Hotham Street, and the Bush.

2205. Then you have increased your supply from the remaining four?—Yes; I am now getting from Bootle an increase of nearly 1,000,000 gallons per day. I am carrying out works there at this present time, and at Dudlow Lane, which is a new station, I am getting 400,000 gallons per day. During 1866, when we were short of water at Rivington, we pumped all that we could obtain from the wells.

2206. If I understand you correctly, you derive nearly as large a quantity from the four wells that you retain as you did when you had seven?—Yes, that is so.

2207. And you derive from the four wells that you retain as large a quantity now as you always did, even before the introduction of the new source of water supply?—Yes, about that.

2208. If I am correctly informed, the water from the wells is hard?—Comparatively hard.

2209. And the water that you derive from your new source is soft?—From Rivington it is.

2210. In what way do you supply the hard water to the different houses?—It is mixed in the reservoir and distributed along the pipes; we mix the one water with the other; there are certain reservoirs in the neighbourhood of Liverpool from which we distribute the water.

2211. What degree of hardness is the water when mixed?—I have here an analysis of samples of mixed water taken from three districts of the town at the time when it was considered desirable to have the water somewhat changed, and this is the analysis to which the medical officer refers:

"To Dr. Trench, Medical Officer of Health to the Borough of Liverpool.

"College of Chemistry,
"Liverpool, June 8th, 1866.

"SIR, Liverpool Service Waters.

"I BEG to hand you herein my analysis of the three samples of "Liverpool Service Waters" left with me for examination on the 23rd May last. The samples were labelled thus:

Sample:—"69, Mann Street."
"6, Hornby Street."
"Abercromby Square."

And represented as having been taken from the service-pipes of the places named.

"An inspection of the waters showed they were quite free from solid matters in suspension, and when viewed through a 10-inch column they presented a translucent and colourless appearance.

"A careful qualitative analysis of the waters severally indicated the presence of carbonate of lime and magnesia, sulphate of lime, chlorides of sodium and of magnesium, silicate of soda, carbonate of soda, *traces of nitric acid* in combination, organic matters, and small though very distinguishable traces of ammonia in each.

"The respective amounts of these several bodies were estimated with the greatest care and calculated to the imperial gallon. The table annexed contains the result thus obtained:

TOTAL AMOUNT of SALINE and other BODIES per Imperial Gallon in the Liverpool Service Water from:

	6 Hornby Street.	69 Mann Street.	Abercrombie Square.
Carbonate of Lime	0·5694 grains.	3·9050 grains.	1·8866 grains.
Carbonate of Magnesia	0·8953 „	3·0359 „	1·2386 „
Sulphate of Lime	3·8750 „	6·2676 „	2·4658 „
Chloride of Sodium	1·7886 „	4·2968 „	1·6010 „
Chloride of Magnesium	0·2865 „	0·3817 „	0·1404 „
Silicate of Soda	0·0211 „	0·0810 „	0·1011 „
Carbonate of Soda	trace.	0·0201 „	0·0250 „
Nitrate of Magnesia	0·6361 „	0·1641 „	0·0922 „
Organic matter and traces of Ammonia	0·7013 „	0·6538 „	0·6670 „
Total per gallon	8·7733 „	18·8060 „	8·2677 „

"The several samples mentioned have a persistent alkaline reaction, from the presence of carbonate and silicate of soda, in them. They have not the property *of dissolving metallic lead* so as to retain it in solution.

"(Signed) SHERIDAN MUSPRATT, M.D.,
"Professor of Chemistry."

2212. I think you stated that you have experienced some disappointment from the original calculations that were made as regards the quantities of supply from the new sources?—Yes, no doubt in the years of small rainfall we have.

2213. So much so that you have not had so large a supply as you contemplated?—That is so.

2214. But nothwithstanding that Mr. Hawksley's propositions with regard to the rainfall have proved to be pretty nearly correct according to that calculation?—That is so. The only error made I think was in taking a mean instead of a minimum.

2215. As engineer to the Liverpool corporation, you have been requested, have you not, to suggest a system by which you could increase the supply?—I have.

2216. In addition to the quantity which you have already, what quantity do you propose to supply?—I propose first of all to go to Bala Lake, to commence with such a quantity by laying down one main as would deliver 15,000,000 gallons a day.

2217. What is the distance from Bala Lake to Liverpool?—Close upon 70 miles along the pipe line.

2218. (*Chairman.*) Do you propose to abandon that area which you described a short time ago?—I never contemplated using it. I was directed to examine it and to report my opinion as to its capacity and the physical possibility of conveying the water to Liverpool or rather to our works at Rivington.

2219. Having examined and reported upon that, and also having examined the Bala Lake district, you preferred the latter?—Yes, I preferred the latter, certainly, to all other sources.

2220. (*Sir B. Phillips.*) You say that the distance is 70 miles, and you propose to recommend Liverpool to derive its water by certain means from a source 70 miles off?—Yes, I have recommended it in the report which I have had the honour of handing in to the Commission.

2221. What is the population of Liverpool?—Within our district of supply I compute that we have 600,000, about one-fiftieth part of the whole empire.

2222. What quantity of water per head per diem do you recommend?—In going for a new scheme I would make a large allowance; but I think nothing less than 30 gallons per head per diem is sufficient. With well constructed works, and with a well regulated supply, 30 gallons per head per diem should be enough.

2223. In any scheme which you might recommend for an increased supply of water to Liverpool, should you feel yourself justified in suggesting or recommending to the local authorities that they should under any circumstances abandon their means of local supply?—If we were to go to Bala, I would not have the slightest hesitation in recommending the corporation to suspend their pumping. I have no doubt that the district to which I have alluded in my report is sufficient to supply Liverpool for very many years to come without any assistance from the home sources.

2224. And you think it would be perfectly safe to discontinue the pumping?—I have no doubt in my own mind that we should be perfectly safe, because the district is so extensive that the quantity of water to be taken for the use of Liverpool from it can be extended as the requirements of Liverpool grow. The whole of this district is capable of yielding 100,000,000 gallons a day for our supply, at the same time giving a sufficient quantity of compensation water down the rivers for the use of those having rights in the water.

2225. (*Chairman.*) When you speak of 30 gallons per head per diem, is that an inclusive quantity, or is it exclusive of water for trade purposes?—For all purposes.

2226. In calculating for the commercial requirements of such a town as Liverpool, as well as the supply of the inhabitants for domestic and other purposes, is an average of 30 gallons per head per diem a sufficient supply in your judgment?—Very much would depend upon the character of the town, whether it is a manufacturing town or not; but speaking of Liverpool, I think that if we had 30 gallons per head per diem, with the power of extending the supply as the town grew, we should have about a fair and sufficient quantity. But I do know this, that the uses of water are being increased in all directions, and that the tendency is to use a larger quantity of water day by day. Such are the household arrangements now that we require a larger quantity of water, from the cleanlier habits of the people and other causes.

2227. What area have you directed your attention to in the Bala Lake district?—The basin of the Dee and also of the Elwy, and the Aled being a tributary of the Elwy.

2228. What acreage do you think would be necessary for the supply of Liverpool in addition to your present source of supply from the wells?—I would take the whole of this district, that is to say, the 35,000 acres which you will see coloured blue, the 14,000 acres, and the 11,000 acres.

2229. I presume that the area of Bala Lake and the gathering ground generally would be sufficient for the supply of Liverpool independently of your present source?—Quite so for a long time.

2230. And the supply would be capable of expansion equal to the growing population of the town?—Yes, that is one of the merits of going into a district where you can extend your supply.

2231. What is the difference in mileage between the

T. Duncan, Esq.

21 March 1867.

district which you have surveyed on the north and the Bala Lake district?—Taking into consideration that after we had got the water down to the Rivington works from the Hodder we should be obliged to continue the works on to Liverpool, there may be about 10 miles difference.

2232. And the difference of cost of course would be in that proportion?—Yes. The Hodder district is wanting in one of the essentials to any scheme; it is not capable of being extended to such a length as the Bala district. The Bala district contains all the elements of a great and good supply, that is to say, the water is pure, it is abundant, and there is plenty of space to gather more.

2233. You propose, do you not, to take your supply direct from Bala Lake and to utilize the lake as a natural reservoir?—Yes, and the plan of making it a reservoir has many advantages.

2234. Would you increase the quantity by tapping?—Yes, by raising it up so as to keep the outflow level up to high-water mark of the present floods. The highest flood mark would be the sill of the by-wash.

2235. What is that beyond the ordinary surface level?—It is about 5 feet, and I should draw off so much below.

2236. Would that flood a large acreage?—No, it would flood nothing more than what is flooded now at high water.

2237. Would not it involve compensation?—It would avoid all compensation so far as flooding new land is concerned. That was one of the objects which I had in view.

2238. Is that quite so; you may have an occasional flood in the winter, or say floods in the year, that is one condition of things, whereas you propose to flood the land and to take possession of it?—No, not to flood the land.

2239. If you raise permanently the surface level of the lake and flood it to the extent of the highest flood in the winter, you are permanently taking possession of so much area, are you not?—I quite understand your question. I would not flood any additional land, because the bye-wash would be of such a width and such a height as would prevent the water rising as it does now by being throttled at the outlet of the lake. By giving it an expanded bye-wash and keeping the head of the water low I should have the means at command of keeping the water down and so preventing any flooding of the land which does not now take place.

2240. My first question is this; do you propose to raise the surface level of that lake and to increase its storing capacity, and your answer, if I rightly understand it, is that you do propose to raise it 5 feet?—Yes.

2241. And I understand that that is to be a permanent raising?—Yes.

2242. Then I want to know what increased acreage that would flood?—I have not ascertained the breadth. The margin of the lake on one side is precipitous; upon the right bank of the lake there is a railway which has been recently constructed and which runs along the very margin of the lake, so that a portion of the right bank as well as the left bank is also tolerably precipitous, and the quantity of additional land that would be flooded, that is to say, the present beach which would be permanently flooded, would not be a very large quantity, but I have not ascertained precisely what it would be.

2243. You would have to take the rail higher up otherwise you would flood the rail, would you not?—No, we should not flood the rail; the rail is about 8 feet above the margin of the lake.

2244. (*Mr. Harrison.*) Is not this what you propose to do, to make your bank sufficiently high to retain the waters at the present highest flood line?—Yes.

2245. And to provide such an extensive bye-wash as would keep the floods that would pass off from rising so high as to flood the lands?—Yes, that is my view.

2246. (*Chairman.*) What quantity do you think this area which you now propose to utilize would yield?—A large quantity. I calculate that the lake would be able to give us 30,000,000 gallons a day before we require to construct any large additional works for compensation water.

2247. Do you know the rainfall of that district?—That is a question which is not very well determined. I have looked at all the available gauges, but in order to be safe I have taken the quantity at what I consider to be the minimum; I have taken it at 36 inches; I have taken off a fourth from that for loss, and then I have allowed of the remainder one-third to go for compensation and the other two-thirds to be taken to Liverpool.

2248. I understand that you have taken off 9 inches, and your evidence is, that there is a loss of from 11 to 12 inches?—That is in the other district. In the Bala district I am inclined to think that the loss would be much less. The rocks are less absorbent; they are of a hard, slatey character; the slopes of the hills are steeper and the waters would come down more suddenly, and would reach the valley in a larger volume in proportion to the rainfall than the water at Rivington does.

2249. At all events the area is so large that it is quite capable of yielding the quantity which you assume?—Yes.

2250. Do you propose to take it by means of iron pipes?—First of all by a culvert which would carry 60,000,000 gallons a day. I propose to make that a permanent work down to the reservoir which you will observe marked on the map near Llangollen.

2251. The population of Liverpool, I think you state, is 600,000?—Yes.

2252. (*Mr. Harrison.*) Are there 600,000 now?—Yes, within the district of the supply which extends over 60 square miles.

2253. (*Chairman.*) Allowing 30 gallons per day what would that make your present supply?—18,000,000 gallons.

2254. And you would give to the culvert, or whatever you construct, a carrying capacity of 60,000,000 gallons a day?—Yes. If you will follow the red line from the bottom of the lake the ground is very favourable for the formation of such a work till we come down close to Llangollen. Between Llantisilio and Llangollen I propose to cross the Dee by a pipe by a special bridge constructed for the purpose.

2255. Do you cross there above the bridge?—Yes, above Llangollen. That would be upon the left bank of the Dee. Then attaining an altitute on the other side I continue the culvert on to the little square mark which you see upon the map. There I propose to construct a reservoir and make straining beds, and from thence by the red line I would go down and cross the Dee again near Holt, then across the Chester and Crewe line of railway, near to Tarporley, then through the Forest of Delamere skirting the high land, and at two of the most convenient points that could be found along the line I propose to construct certain relieving reservoirs; thence I should take it down across the Mersey by a special bridge over the river above Runcorn, and then on to Woolton.

2256. Is there any navigation above that point?—Yes; the bridge would have to be sufficiently high, just as the railway bridge which is now constructed there is sufficiently high, to admit of the craft which go up the river to pass through it. Then I go on to Woolton Hill, which is high land, in the neighbourhood of Liverpool; and from thence I propose to make connexions to the various reservoirs in the neighbourhood of the town.

2257. (*Colonel Harness.*) To what depth do you propose to draw the water in Bala Lake?—I have suggested 2 feet below the bridge at the present time.

2258. What would be the depth below the level of the lake?—It would altogether give me a power over the lake of from 6 to 7 feet.

2259. What capacity of storage do you calculate upon?—With the water which would flow into the lake, taking 20,000,000 gallons a day as the quantity to be supplied to Liverpool, it would be about 190

days. Then the other part of the project is this: from the little square dot which you see in the neighbourhood of Llangollen I would for the present time content myself with one pipe to deliver 15,000,000 a day, taking land of sufficient width, and making the permanent works, the bridges, and other appliances, sufficient for the addition of other pipes as they might be required.

2260. (*Chairman.*) Do you propose to have pipes all the way?—There is a small portion in the neighbourhood of Broxton, and a small portion near Frodsham that will be open, but I have calculated for pipes all the way from the reservoir upon the shoulder of the hill near Llangollen.

2261. How many pipes would you have?—In the meantime, until the supply is required to be greatly extended, I would have only one which would be sufficient to supply 15,000,000 gallons a day, and I would add pipe after pipe as necessity arose.

2262. What size would the pipe be?—A 44-inch pipe. I have taken the same data that we have in the Liverpool works.

2263. Do you propose to use a wrought-iron pipe?—In the valleys where the pressure would be greatest, I think it is quite possible to obtain steel pipes which would be much lighter, and I have been in communication with several manufacturers of steel in the country, and they tell me that they think that there is no great difficulty in obtaining steel pipes. Chemists tell me that steel pipes are less subject to corrosion than iron pipes, so that if we could obtain steel pipes they would be very little more expensive than the others. Wrought-iron pipes are more secure than cast-iron pipes, but I have calculated for cast iron.

2264. Your other system of supply has been in operation for 10 years, has it not?—Yes.

2265. What has been the effect of the soft water upon the iron pipes?—To produce an infinite number of small tubercles; those have grown up, and they project, in many instances, for about three-quarters of an inch, reducing the diameter of the pipe, between point and point, by $1\frac{1}{2}$ inch.

2266. And thereby, I presume, increasing the friction?—Yes; they form an infinite number of little eddies, and it is not only the space that they occupy in the pipe, but from my own observation I believe the effects extend much farther into the interior of the pipe and disturb the current; but comparing a pipe of $1\frac{1}{2}$ inch less diameter with the present pipe, I know that the pipe of $1\frac{1}{2}$ inch less diameter would conduct from Rivington to Liverpool a larger quantity of water than the 44-inch pipes do with those little tubercles.

2267. (*Col. Harness.*) Have you formed any calculation of the present discharge of those pipes?—They have fallen off very nearly 25 per cent., part of that I attribute, however, to their passing over some coal-fields where accidental depressions have taken place, and I have it under contemplation now to put in a number of small air cocks wherever we have those depressions, so as to take off the air, for I think the pipes have become partly choked, and will not run full.

2268. Have you got an arrangement for relieving those summits?—Yes; we have for the summits which existed originally, but accidental summits have been created, which we have not been able to overtake.

2269. (*Chairman.*) I suppose that apart from those depressions your pipes are always charged?—Yes, always charged, and running full under pressure.

2270. And yet, notwithstanding that, they are in the condition you have described?—Yes, that I find to be so when we have a fractured pipe and take it out.

2271. Where there has been no depression you do not attribute that condition of the pipe to the depression that might arise from the land sinking, and allowing the air to be in the pipe, but it is general throughout the pipe?—I am speaking now of the present state of the pipes.

2272. I refer to case of pipes that are level laid as they were originally, and under constant pressure, yet when they have been taken out for the purpose of examination and repair you have found them in the condition you have described?—Quite so, they are all alike in that respect.

2273. (*Mr. Prestwich.*) Have you had to replace any pipes in consequence of this deposition or incrustation?—No, we have had to replace fractured pipes occasionally, and in doing so I have discovered the condition of the pipes.

2274. (*Col. Harness.*) In the town delivery you would get some means of actually measuring the effect, would you not, because you have not had those sinkings there?—We have had no depressions in the town certainly, but the draught varies so in the town that I have never taken any means of ascertaining the difference of delivery in the pipes at different times, but I have no doubt of what takes place.

2275. That would admit, would it not, of a nice experiment?—No doubt. I will state to the Commissioners what I have done in the town of Chorley where the water has been laid on for 16 years. The qualities of the waters of Rivington and Chorley are very much alike, in fact they come from similar districts, and at Chorley we have an application at this moment to take up and relay a number of pipes in the town, because they have become choked up in consequence of corrosion taking place of the same character as I have now described. Some five years ago we had occasion to lift one of the small pipes which extended along the ridge of a hill where there was not much draught of water, and when taken out one could scarcely see through the pipe, it had become so incrusted.

2276. What was the diameter of that pipe?—It was only a 3-inch pipe. I have taken those pipes out and put down larger ones.

2277. (*Chairman.*) That projection which you have described to us is really from the substance of the pipe, is it not, and not a deposit?—Any matters that may be in suspension will adhere to the oxigenation of the pipe, and the little particles that may be in the interior of the pipe form a nucleus around which they gather.

2278. Have you taken any precaution against that by using the patent coating process?—I coat all the pipes that I lay down now by Dr. Angus Smith's process.

2279. What has been your experience of it?—I had occasion to cut out a pipe not more than three months ago which had been down for eight years, and I found the coating upon it not quite perfect, but in a great measure so. I consider it a very great advantage to coat all the pipes with that process.

2280. (*Mr. Harrison*) Were your pipes originally coated from Rivington Pike?—They were not.

2281. (*Chairman.*) In any pipes that you lay down now you adopt that or some other system of coating?—I adopt that system; I do not know of a better; I believe it to be the best at present known.

2282. The iron, I believe, is subjected to great heat and then put into the coating composition?—They have an apparatus at various foundries where they cast pipes. They warm the pipes in a species of oven, and they have a large tank in which this molten composition is kept; they dip them in, a number together when they are small, and fewer if they are large, or probably one if it is a very large pipe; they then take the pipe out and roll it away and allow the coating to dry, and it forms a perfect glaze upon it.

2283. What has been the external condition of your pipes that have been covered for a number of years?—A good deal depends upon the quality of the soil, but there is very little change upon them in general.

2284. (*Mr. Prestwich.*) Is there any difference in the condition of the pipes between Rivington and the reservoir at Liverpool, where you mix the water, and that of the pipes between the reservoir of mixed water and the town?—I cannot say there is. There is a tendency to the same kind of state in the pipes in the town that there is in the larger pipes bringing the water from Rivington.

2285. At what height do you deliver the water at Woolton Hill?—250 feet.

T. Duncan, Esq.

21 March 1867.

2286. What is the height of the starting point at Bala Lake?—530 feet I think is the water level.

2287. Do you base your estimated quantities entirely upon the assumed rainfall which you have just named or upon any gauging of the water?—Upon the assumed rainfall which I have taken and supposed to be the minimum.

2288. What is the nearest rain gauge in the Bala district?—There is a rain gauge kept at Bala at which I could learn nothing when I was there myself, but from Mr. Bateman's pamphlet I have looked at the matter, disregarding all those gauges, and taking what my own experience led me to; comparing that district with others, I have assumed a minimum rainfall of 36 inches, which I believe is lower than it really is, and which will make me quite safe.

2289. But you have no knowledge of what has been the maximum rainfall in a term of years at that spot?—I found nothing less than that in looking over the gauges of that district which are at all approaching to the same altitude.

2290. Do you know what the maximum rainfall of that district has been?—Over 70 inches; in one place I saw that the rain gauges had indicated over 100 inches.

2291. Notwithstanding the water is so pure, you think it necessary to filter it before delivering it to Liverpool?—I would pass it through a series of strainers; my object in taking the water at the lake was to avoid the turbid waters which occasionally come down the Dee. On my first visit to the Dee it happened to be after a rainy day, and the water was altogether unfit to take out of the Dee to use for the supply of a town. On the second day, when it did not rain at Llangollen, when I got to Corwen I found the river swollen and I met the flood coming down; there had been a very heavy thunder shower and the water was quite turbid; that confirmed me in my previous opinion that the lake was the proper place to go to.

2292. What quantity of organic matter do you find in the Rivington waters before filtering them?—I have here a great number of analyses with me, and the highest is 2·59; that is from a stream whence the water was taken in a time of drought, and hence the earthy salts and other matters were in great abundance in proportion to the quantity that was flowing down, but taking the water from the reservoir it was 1·12.

2293. What was the quantity of organic matter at the reservoirs at Liverpool?—I am not able to speak to that off-hand, but I think it does not exceed 2.

2294. Do you know whether it loses any of that in in the transit from Rivington to the reservoir?—I should say not; it is very much the same in quality.

2295. The quantity of organic matter in the water from the wells I see you have taken at 0·7?—Yes.

2296. But the wells contain, do they not, a larger proportion of inorganic matter?—Yes.

2297. The chief cause of the hardness of this well water, I perceive by the paper which you have placed in my hands, is sulphate of lime?—Yes, that is the hardening quality.

2298. And the chief cause of the slight degree of hardness in the Rivington Pike water is the existence of carbonate of lime?—Yes, carbonate of lime and a little magnesia.

2299. Have you found that the mixed waters, which you now deliver in Liverpool, have any effect upon the lead pipes?—No, the pipes become coated inside by the earthy salts which are held in suspension.

2300–1. Have you had any opportunity of examining the effects of the Rivington water by itself upon lead pipes?—I have not, but I believe that after the lead is once coated over the water has no effect whatever upon it; after passing water down through a new pipe or a new cistern, the action of the water on the lead ceases in a very short time.

2302. At first you imagine that the water does act upon the lead?—At first chemists tell me that it has an action, but I have not found in practice that we have that continued action.

2303. (*Col. Harness.*) What does the capacity of your catchment reservoir at Rivington amount to?—3,180,000,000 gallons.

2304. Can you tell me what that is in inches of rain?—I cannot tell you off-hand.

2305. I see that the quantity which you return as compensation is the same in every year; are you always giving out compensation?—Constantly.

2306. Whether the river wants it or not?—We are bound to give it out; if we do not do so we are under penalties, and we have had to pay those penalties.

2307. Supposing the river were in flood, would you still be giving it from your reservoir?—We have always done so.

2308. Then every day you give out a definite quantity of water from your reservoir?—Every day, except in the case of the gauge at Roddlesworth, which we have succeeded in purchasing, 1,800,000 gallons a-day, and there we do not give out water on Sunday; from 6 o'clock on Saturday evening up to 6 o'clock on Monday morning the sluice gates are shut down.

2309. Then you are sometimes increasing the flood?—Yes, if there is a succession of heavy rains, and our reservoir is full, we should let the water down just the same.

2310. Does all the water come into your reservoir?—All the water of those streams that we take when we impound them.

2311. Therefore there is no flood in the river unless your reservoirs are overflowing?—In that part of the river immediately below our embankment there would be no flood unless we let it out.

2312. But below your embankment it might be in flood?—Below our embankment it is frequently in flood.

2313. From other streams might it be in flood?—From other streams it might be so.

2314. But you would still give them the 8,300,000 gallons?—We must do so.

2314*a*. How do you measure the quantity which runs to waste, is it by calculation or measurement?—By calculation over the waste weir, but the quantity which we get from the district for the use of Liverpool is measured into the reservoirs, where we have the means of measuring it. That which passes over the waste weir I calculate in this way: I know whenever the river is in flood, and when we are running to waste, that we are passing down into the reservoir all the rain which falls during that time.

2315. Because you assume that at such a time there is no evaporation?—There is neither evaporation nor absorption, because the quantity of rain has so saturated the ground that it comes down very much like water from a slate roof.

2316. Your calculations are based upon your readings of your gauges?—Yes.

2317. (*Sir B. Phillips.*) You had a good deal of cholera last year in Liverpool, had you not?—We had a good deal of cholera.

2318. Have you any idea from the reports of the medical officers as to the influence of the character of the water upon the health of the town?—Excepting those documents which I have handed in I have no other means of arriving at a theory on that question.

2319. Have you yourself considered the subject in any way?—I have looked at it and regarded it with some degree of anxiety. I was very anxious that the water should be of the best and purest quality and most abundant in quantity during that time, so that places could be kept clean.

2320. (*Chairman.*) Was the outbreak of cholera in your judgment due at all to the insufficient supply apart from the quality of the water?—It is very difficult to say what it was owing to; no doubt if there is a scarcity of water it will influence the state of the public health and the outbreak might have been partly due to that, but I would not venture to say that it was so.

2321. I suppose in Liverpool especially you import

a large amount of disease?—We do; it has a peculiar population.

2322. (*Mr. Harrison.*) Having investigated the whole of this subject for the corporation, and looked at all the various sources of supply, have you come to the conclusion that Bala Lake is the best of the whole?—I have.

2323. If that were supplied to Liverpool you contemplate abandoning all your well supply?—No doubt.

2324. Would you also contemplate abandoning the supply which you now get from the Rivington Waterworks?—That would be a question for the corporation to deal with. My own private opinion is this, that we could sell a large portion of the yield from Rivington to the districts which we pass through. I know that at this moment St. Helen's would be very glad to take a very considerable quantity from us. I believe that Warrington is also short of water and Wigan has a supply of its own, and whether they might be inclined to come to an arrangement with us I do not know, but coming along the district I have no doubt that we could get rid of all the Rivington waters.

2325. Taking it that Bala Lake is about as pure and soft as any water, have the corporation endorsed your views that Bala Lake is the best place to take it from?—There is a division of opinion in the corporation upon that subject, some thinking that there is no need to go for water to Bala or to any foreign source, that we have plenty of water from the red sandstone. Unfortunately I differ from them in that respect. Others again think that the time has not yet come for going for such a large scheme. There again I differ from them. They might be inclined to go for a large scheme if they could see a pressing necessity for it, but I have had this subject constantly before me for a length of time, and I have come to the conclusion that if Bala is not taken for Liverpool other parties will come forward and take it.

2326. Then perhaps the view of the corporation may not be one so much as to the quality of the water as to the actual cost which they would have to incur to bring it?—I have no doubt that that has great influence over their views.

2327. But in your mind there would be, I presume, from what you say, a great advantage in having the pure and soft water of Bala Lake delivered into the town of Liverpool generally?—I have no doubt about it.

2328. Have you contemplated at all in your scheme supplying any other towns in the course of the pipe?—I have thought of Chester and also of Birkenhead. It is quite possible, from the line below the reservoir, near to Llangollen, to supply those towns. Indeed, I may state further that a project was in Parliament a short time ago for carrying a tunnel under the Mersey, and I have thought that if the scheme could be accomplished the main pipe might be taken down that way.

2329. That is not done yet, you know?—No, it is not done; but still the other way is open, and hence I have proposed the other way.

2330. Still, at the elevation at which your pipe would be and your head of water, you would be able to supply a great number of those places which come within range of it, especially as they are only small towns?—No doubt.

2331. Crewe is a large place, as we know, and Warrington is pretty well supplied, is it not?—No; Warrington is not very well supplied. I had occasion to be in Warrington some time ago, and investigated their supply, and I know that they have it in contemplation to go further to obtain new supplies, which is a certain proof that they require more water.

2332. When you calculate, no doubt cautiously, upon an available supply from about 18 inches of rainfall in this district, do not you think that that is rather low, although it may be perfectly safe?—I have done it simply to avoid committing an error which has proved fatal to a great many waterworks projects. I know I am within the mark; and I know this also, that what water we do not require would still go down the rivers.

2333. But if more water were required than what you are taking you still have the means within the district of adding a larger watershed to your supply, and even to double it?—I know no district with such capabilities.

2334. You have merely included a certain area, and if it had been desired you might have doubled or trebled the area of watershed and brought it into your conduit from that district?—Yes, that might be done easily.

2335. In the case of Loch Katrine they do not filter their water there at all, do they?—No, they do not.

2336. Do they filter it at Manchester?—No.

2337. They have a large number of reservoirs, have they not, in which the water settles, and they draw it off from one to the other?—They have a larger quantity of spring water there than we have in the Rivington district, and they drain that off and appropriate it for the use of the town, giving out the ordinary water for the millowners.

2338. Have you based your estimate upon actual sections taken of the line of the proposed conduit?—I have taken no levels beyond those which I found upon the Ordnance map. I know what the level of the lake is, and I know what the level of the Dee is down at Llantisilio by the Ordnance map. I also know from observation what the level of this reservoir would be, because I have allowed a certain fall per mile, the ground being of a sloping character, and I have walked over the ground and fixed upon this spot. I also know the levels at the several other points along the route, but I have not made any actual section. I believe that at the time when Mr. Rawlinson proposed the Dee scheme—what is termed the Bala Lake scheme—he had sections made over the whole area, but I have not been able to obtain a sight of them. However, I know that between the various points I am quite correct, or at least as near as may be.

2339. Have you seen the scheme that is proposed by Mr. Hemans?—I have.

2340. He proposes to take water from the lakes of Westmoreland and Cumberland, and in his plan his main conduit comes over the lower part of your Rivington works and at a level of 30 feet above them, does it not?—Yes.

2341. If such a scheme were carried out, and he were to deliver water into your pipes, would that answer your purpose equally well?—It would answer my purpose, no doubt, so far as the mere delivering of the water is concerned, but that water would be delivered 24 miles from Liverpool, and we should have a line of pipes to lay down to convey that water over a series of coal fields, extending from the base of our works, I may say, on to within eight miles of Liverpool.

2342. We know that in the Wigan district as you go over the surface of the ground it is nothing but a series of pools of water. Do you find much difficulty in maintaining your pipes there?—Yes, I have found a great deal of difficulty. At this very moment the subject is before the Water Committee; we have a tunnel in the neighbourhood of Rivington about three miles from it. The owner of the Minerals has applied to us to know whether we will purchase the coal under the tunnel or not, and I have had it in serious consideration whether I shall not get another line of tunnel, lay pipes in it, abandon the old line, and let them take the coal as fast as they like; so long as we have our pipes and can get down to them, we can always keep them on something like a level, and even if they are not very level, so long as there are no air locks, we are perfectly safe, but as any party passing under may break the tunnel in working the coals underneath, and may let our water down into the mine, and cut off our supply, then it becomes a very serious question.

T. Duncan, Esq.

1 March 1867.

2343. In Staffordshire, in the case of the canal belonging to the North Staffordshire Railway Company, they had to pay, had they not, for one single seam of coal, upwards of 20,000*l.* as settled by arbitration?—I think so; my estimate of the cost of the coal under this three-quarters-of-a-mile tunnel will amount to several thousand pounds, certainly from 5,000*l.* to 7,000*l.* We have, I may say, purchased at several points, where there are faults, small pieces of coal, so as to let the ground down easily.

2344. Have you yourself, living in Liverpool, ever happened to have stayed for a length of time in a district where you got very soft water, in Manchester, for instance?—Yes, I have lived for some time there.

2345. Have you found a difference between the waters?—I like soft water better than hard. I have lived where I have had nothing but rain water. During the time that I was with the late Mr. Walker in the Fern Islands I had nothing but rain water for seven months together, and liked it better than the water on shore, after I got accustomed to it.

2346. Has the question of the quality of the water been a subject of discussion with your town council, as to the hardness or the softness of it?—Not so much that, as whether it is to be a supply from home sources; the quantity, if I am not mistaken, has been the great object and the price. There are many gentlemen in the council very desirous, and indeed I believe they are all very desirous, of seeing the best quality of water, but they consider the red sandstone water the finest quality water for table use in the world, although it is not by any means the best quality of water for general purposes.

2347. You have no Bill this session before Parliament to extend your water supply?—No, I am at present engaged in sinking two wells, in fact I have got orders to sink a third shaft, and put down bore-holes, in order to test more than has ever yet been done the capabilities of the red sandstone around Liverpool, for furnishing an additional supply.

2348. Have you found that the pumping from the red sandstone has diminished in quantity?—My experience is that the water has diminished in the red sandstone; the water line is gradually lowering.

2349. (*Mr. Prestwich.*) There are other wells furnishing now some water, are there not?—There are other wells within our district of supply. We draw altogether, from recent investigations which I had occasion to make, somewhere about 15,000,000 gallons per day of water, which is 1,000,000 gallons to four square miles, and taking 60 square miles as our district of supply, I find from my own experience of the wells which I have under my management, that we are gradually lessening the quantity. At Green Lane well, which is a very excellent red sandstone well, when we had finished our bore-hole, about 1855 I think it was, our yield a short time after that was about 3,300,000 gallons a day. Taking the yield during last year, at the same point, I found it was down at 3,000,000 gallons a day, so that is 10 per cent. off the maximum yield in 10 years, or about one per cent. per annum.

2350. Had any wells in the meantime been constructed in the neighbourhood?—Some others have been constructed; one well has been constructed by the railway company not far from it, but they have not begun to pump from that well.

2351. But are there any wells within a distance to draw water from the same sources of supply?—Not any well of consequence excepting that well.

2352. (*Col. Harness.*) Have any of the other wells increased in the same period?—None of them have increased except at Bootle, which I am now engaged upon. There, by sinking that well from a depth of 30 feet from the surface, I have lowered the body of the well 70 feet, making it in all 100 feet, and I have taken off the head from the bore-holes which yielded the water before, and we have got an increase of water there from about 900,000 to 1,000,000 gallons per day.

2353. (*Chairman.*) Are you sinking two fresh wells?—Yes, we are sinking two fresh wells at present, and another well I am about to sink.

2354. Would not that tax the same source?—They are at a considerable distance from each other, but I am not sure what the effects may be.

2355. What is the extent of the depression of your water?—I find at Bootle that I am obliged to go down somewhere over 50 feet to get the same quantity from a well under similar circumstances. Compared with my former experiment, when we obtained at a certain depth from the surface a maximum supply of so many gallons per day, to get the same quantity I was obliged to lower the water down to take so much head off, so that it would spring up through the bore-holes.

2356. (*Mr. Harrison.*) You have only calculated upon raising the water of Bala Lake to the extent of 5 feet; supposing you required a much larger supply than that which you have mentioned, I presume you would have resort to additional reservoirs up in the hills?—Precisely so. There is one point on the Treweryn stream where we could have 14,000 acres impounded in two reservoirs where the sites are exceedingly favourable, and which would hold as much water as we have at Rivington altogether.

2357. Do you think that the difference in the nature of stratification there would enable you in that case to do with artificial reservoirs without filtering?—I propose to supply as compensation all the water that I would derive there, leaving the lake for the use of Liverpool, and giving the compensation water from artificial reservoirs.

2358. (*Mr. Prestwich.*) Do you know the difference between hardness of the waters in the wells and those from the new red sandstone?—I think it is pretty nearly a constant quantity. There is no doubt of this, that the longer we have worked these wells the harder the water becomes. At first the Green Lane water was somewhere about 4½ degrees of hardness, I think, speaking from memory, and now I believe it is somewhat over 7, so that it has increased.

2359. Is there then any difference in the hardness of the water before and after boiling?—It softens by boiling.

2360. (*Mr. Harrison.*) Do you find during your 20 years' experience of Liverpool that the habits of the people have altered much as to the consumption of water, and also that the large sanatory improvements which have taken place very largely added to the quantity consumed per head?—No doubt they have.

2361. Can you give us what in your earlier period was the consumption per head?—It was about 11 gallons per head per day, about 20 years ago.

2362. It has been gradually increasing?—Yes; it has been gradually increasing as drainage works have progressed.

2363. Do you recollect what the consumption at present is in Glasgow?—It is very large, somewhere near 50 gallons per head, I believe.

2364. Is that wasted?—There is no doubt that a very large portion of that is wilfully wasted.

2365. Do you think that in a large town where sufficient care is taken to prevent waste, 30 gallons per head would be sufficient?—If you have power to prevent waste, I believe that for a town such as Liverpool, 30 gallons per head per day would be about the right quantity. That quantity will no doubt go on increasing as the population increases, and it is very rapidly increasing.

2366. Going back to a period of not more than 10 years ago, was not the regular standard given in evidence by all water engineers before committees a consumption of about 20 gallons per head?—Yes, 20 gallons per head, with which I never agreed, I took it always as being too small.

2367. But still that was the standard?—Yes, that was the standard, and evidence was given before committees of parliament that that was the right quantity to calculate; indeed, some engineers at this day say

that 20 gallons a day is the right quantity, but I cannot agree with them.

2368. Do you feel quite confident, having had that view when 20 gallons was mentioned, that 30 gallons will be sufficient looking at the altered habits of the people?—I should be very sorry to say that 30 gallons will be found sufficient, 25 years after this. I do not say it would. I consider that it is the duty of everyone having the responsibility of obtaining a supply of water for a large community to have a very large margin indeed—over 30 gallons per head.

2369. Has not one of the great sources of increase been the introduction of waterclosets?—Yes.

2370. Another is the introduction of baths?—Yes, and baths also.

2371. And the flushing of the sewers?—Yes, that also is a very large source. It is essential to the health of a town to have the sewers well flushed, to have waterclosets to houses and to have an abundant supply for baths.

2372. Taking the question of the supply of water to London and looking to the probable necessities 20 years hence, the increase in every possible way through sanitary measures and everything else, what should you put, looking forward to those things, as the fair amount per head per day for London, say 20 years hence?—I should say that with the increased population which would be found to exist at that time a larger quantity per head than 30 gallons would be necessary. All our social habits and sanitary arrangements tend to an increased quantity of water being used.

2373. What should you put it at?—I should not be at all astonished if it reached 50 per cent. upon that quantity, making it 45 gallons per head.

2374. In calculating, therefore, upon any large scheme, and looking forward, you would look upon that as something about the measure which ought to be taken as the possible measure?—Somewhere thereabouts. If it is possible to obtain such a quantity. Any district for the supply of London must be capable of being extended far beyond its present wants.

2375. What is the increase in the population per annum in Liverpool or within the district which you supply?—The best proof that I can give with regard to that is the number of tenants that we put on year by year, and taking them at a certain number of persons per house. In 1863 we put on 3,763 new tenants; in 1864, 3,950; in 1865, 3,537. I have not the return for 1866, but the number would be close upon 4,000. Taking them at six individuals per house, you get there very close upon 20,000 persons per annum added upon an area of 60 square miles.

2376. Something like three per cent.?—Yes.

2377. (*Chairman.*) May you not have in the same proportion an increase of customers, or may not parties who are not now taking a supply of water take a fresh supply, so that the proportion does not diminish?—No doubt; still we have gone on so steadily that I am looking to a steady increase year by year of the population, looking to the number of new houses built.

2378. I presume the principle of waterclosets is becoming general?—Yes, the council of Liverpool are adopting that rule, abolishing all cesspools and privies in the town and making what are called trough waterclosets in courts, and many of them take a large quantity of water.

2379. (*Mr. Harrison.*) Looking at such a scheme as this which you are suggesting coming before a parliamentary committee, do you calculate that you would have a considerable opposition from all the millowners and people upon the banks of the Dee, or are there not many rights of that sort to be interfered with?—When I wrote the report, which I have handed in, I was led to believe that we should have a much larger amount of opposition and stronger opposition than I am now inclined to give credit to. I have seen several parties interested in the matter, both landowners and others connected with canals, and I have been told there is less danger of such opposition as I have looked forward to than might be expected.

2380. Would it not add to your parliamentary case whenever you go for your Bill, if you were to include a supply to every town within a moderate distance that could be supplied from this source?—No doubt of it.

2381. And in that case the first portion of your conduit you would make of sufficient size, I suppose, it being an open conduit, to meet any future contingencies, or so construct it that by adding to the size of it you might look ahead of the quantity of water which it would have to convey at first?—I have provided my conduit for 60,000,000 gallons a day; because in constructing a conduit to convey 60,000,000 and one to convey 30,000,000, the actual expense is not at all in the ratio of the quantity; therefore, I have put down that portion of the work as a permanent one till such time as Liverpool shall be twice as large as it now is.

2382. What made you give up the idea of going to the lake district, was it on account of its being more expensive, or what?—First of all, my attention was directed to Windermere and I found that too low, and when I calculated the pumping, I found the cost would be too great. Then I looked to Ullswater, and I considered that to be a most expensive scheme, from the tunnelling and all the other works, and with regard to Haweswater, the same kind of thing obtained there. Besides, with regard to Haweswater, although the rainfall is greater, yet the natural drainage into the lake is not very large, hence, other works would have to be constructed and there would be long and expensive tunnels, and the distance was too great. Taking all things together, none of the schemes that I investigated presented the same favourable features as the Bala Lake scheme.

2383. (*Chairman.*) Do you at all anticipate opposition from the landowners on the area of your Bala Lake gathering ground?—No, I do not. I do not think that the landowners on the gathering ground unless they are really touched by our works have any right to appear in Parliament against the scheme. The water has passed from them.

2384. What prohibition to secure the purity of the water would you ask Parliament to impose upon the parties owning the land which you propose to pass through?—Simply that they should erect no works upon the streams that would render the water unfit for domestic purposes.

2385. For instance would you prohibit the working of lead mines?—In this district to which I refer, the Bala district, there is not a lead mine. There is one mine worked to a moderate extent, and that is a gold mine. I have looked at the colour of the washings coming down from it, and before they pass 100 yards into the lake all the turbidity is gone, the whole of the matter which was held in suspension has been precipitated, and the water becomes pure.

2386. I suppose a series of settling tanks would get rid of the discolouration and, probably, a great deal of the mischief?—That would get rid of the discolouration, but then there may be other matters in the waters from mines which might render them unfit for domestic use.

2387. Are you aware that some landowners in Wales have had their attention directed to this question of water supply and are under the impression that they have some property in the water?—I am aware of that. I have been spoken to by a Member of Parliament on the subject, and I believe it is his intention to bring a Bill before the House this year to enable him to borrow money to construct reservoirs. If he did so then he would have some property to sell, because he would be impounding the water and saving any community who might go to the district for water of so much expense as they would otherwise be put to, to secure the quantity being retained on the ground for distribution as it might be required; then I think he would have a fair claim.

2388. Did he state to you the terms on which he would be prepared to do that?—No, he only expects to be able to obtain powers to borrow money for that purpose, and I think that might be a legitimate course.

T Duncan, Esq.

21 March 1867.

2389. (*Mr. Harrison*). When he talks of spending perhaps 5,000*l.* in making a reservoir I presume that he cannot have an enlarged idea of what is necessary?—He would be expending that money and saving possibly 5,000*l.* to the parties below, but after the water passes his own estate he has no right in that water.

2390. (*Mr. Prestwich.*) Have you made some estimate as to the cost of getting the water from Bala Lake to Liverpool?—I have estimated it at 1,500,000*l.* That includes the purchase of land for the line of pipe and for the conduit, making a conduit capable of conveying 60,000,000 gallons a day, and for all the land that would be required for reservoirs along the line and for the pipe line.

2391. How much a mile does that amount to?—The distance is 70 miles. I have taken the pipe line for a 44-inch pipe at 6*l.* 10*s.* per lineal yard. That includes land and other works.

2392. (*Chairman.*) Does it include easement as well?—Yes, that includes the whole.

2393. And severance where it occurs?—Yes, all expenses whatever, and I have here the details of the estimate, which I beg leave to hand in.

The witness delivered in the following estimate:—

BALA LAKE SCHEME.—DETAILS OF ESTIMATE.

Estimate for 8-Feet Diameter Culvert.

Section No. 1.

1 yard in loose earth:—	£	s.	d.
Earth excavation, 16 c. yards at 6*d.*	0	8	0
Concrete 2¾ „ 8*s.*	1	2	0
Rubble arching 2¾ „ 12*s.*	1	13	0
Blue brick lining 1 1/10 „ 40*s.*	2	4	0
Filling, trimming, &c.	0	5	0
Land	0	5	0
	£5	17	0

Section No. 2.

1 yard in shaly rock:—	s.	d
Earth excavation, 8 yards at 6*d.*	0	4	0
Rock do., 3·4 „ 2*s.* 6*d.*	0	8	6
Rubble arching 2¾ „ 12*s.*	1	13	0
Blue brick lining, 1 1/10 „ 40*s.*	2	4	0
Asphalte lining, ·458 „ 1*s.* 2*d.*	0	5	6
Filling and trimming	0	5	0
Land	0	5	0
	£5	5	0

Section No. 3.

1 yard in compact rock:—	£	s.	d.
Earth excavation, 8 yards at 6*d.*	0	4	0
Rock do., 2·8 „ 2*s.* 6*d.*	0	7	0
Rubble arching 2¾ „ 12*s.*	1	13	0
Blue brick lining ·55 „ 40*s.*	1	2	0
Filling and trimming	0	5	0
Land	0	5	0
	£3	16	0
Mean of the three Sections	4	19	4
Contingencies	2	0	8
	£7	0	0

Works at Bala Lake:—	£	s.	d
1,320 lineal yards embankment at 40*l.* per yard	52,800	0	0
Byewash, 15,000 square yards at 1*l.*	15,000	0	0
Bridge, 150 yards in length	4,320	0	0
Land, 10 acres at 250*l.*	2,500	0	0
Sluices	5,000	0	0
Tunnel, valves, &c.	2,000	0	0
Walling around byewash and cutting	1,000	0	0
Contingencies	17,380	0	0
	£100,000	0	0

Reservoir at Tryweyrn:—	£	s.	d.
Embankment, 400,000 c. yards at 1*s.*	20,000	0	0
Land, 450 acres at 40*l.*	18,000	0	0
Byewash, sluices, contingencies, &c.	12,000	0	0
	£50,000	0	0

Aqueduct near Llangollen	£50,000	0	0
Aqueduct across the Dee	£25,000	0	0
Aqueduct across the Weaver	£25,000	0	0

Aqueduct across the Mersey:—	£	s.	d.
300 yards at 300*l.* per yard	90,000	0	0
Contingencies, &c.	10,000	0	0
	£100,000	0	0

Estimate for 44-inch iron pipe:

Pipe 1⅛″ thick = 1·08 yard per ton, at 5*l.* 10*s.* per ton.

	£	s.	d.
Cost of pipe per yard	5	1	10
Laying, labour, and material	0	15	0
Land	0	3	4
Contingencies, valves, &c.	0	9	10
	£6	10	0

Elevation at Bala	530	feet.
Fall to Plas Uchaf	36	„
	494	„
Deduct strainers, &c.	20	„
	474	„
Level of Kensington	222	„
	252	„

Length of main from Plas Uchaf to Kensington 53½ miles.
Fall per mile, 4·71 feet.

2394. (*Mr. Harrison.*) Have you a section of the tunnel?—Yes (*producing the same*), I have taken three different sections. I have a very large margin for contingencies of getting over streams.

2395. You do not propose, do you, at any portion of your aqueduct or conduit to leave it open to the atmosphere?—At no place, because the rain water flowing down the slope as it must do in heavy floods and thunder-storms, would get into the conduit and contaminate the water which would otherwise be pure.

2396. What is your fall per mile?—18 inches. I have handed in a sketch that I made of it at the time. A part of the work will be in concrete lined with blue brick and cement.

2397. (*Chairman.*) Would you use Staffordshire bricks?—Yes, or I might line it with good bricks of the country, the Welsh bricks, which would come in cheaper and be equally good.

2398. (*Mr. Prestwich.*) What length of tunnel have you?—Of culvert, about 23¾ miles out of 70.

2399. (*Mr. Harrison.*) The greater part of the work would be cut and cover, would it not?—Yes, the whole of it, excepting a short length of tunnel going through about three quarters of a mile at two points, included in the 23¾ miles.

2400. (*Mr. Prestwich.*) What would be the cost per mile of the 70 miles for delivering 60,000,000 gallons to Liverpool?—13,000*l.* per mile for the culvert and one line of pipes, exclusive of the aqueducts, or carrying bridges over rivers. The largest one crossing the Mersey I set down at 100,000*l.*

2401. (*Mr. Harrison.*) What is the length of the aqueduct there?—Somewhere about 300 yards.

2402. And you put that at 100,000*l.*?—Yes, 100,000*l.*

2403. Do you not think that you have made a very liberal estimate for it?—I have made a very liberal estimate for all the works, because I do not wish to get into difficulties. 300 yards I have put at 300*l.* per yard, or 100*l.* per foot, the contingencies I have put down at 10,000*l.* I have had an offer guaranteed for my estimate. I have taken a very liberal view of the whole subject.

2404. Have you at all studied Mr. Bateman's project for bringing water to London from the hills in Wales?—I have looked at it attentively. In fact I knew Mr. Bateman was engaged upon that scheme a couple of years before the pamphlet was issued.

2405. I will ask you as a general question on the

merely physical practicability of the scheme, you do not at all doubt that?—I have no doubt whatever of its practicability.

2406. But you probably have not gone into it in any way that would enable you to form any opinion as to the estimate?—I have not.

2407. Have you at all gone into the matter as to the amount of rainfall which Mr. Bateman has taken and based his calculations upon?—I have looked at it and I think Mr. Bateman is as nearly right as may be, looking at the guages which I have seen.

2408. He has taken 36 inches, although you have only taken practically for Bala about 18 inches. After making allowance for waste do you think that having regard to the different rain gauges that you have examined he might fairly calculate upon 36 inches?—I think he is very nearly right. The district from which he takes his water is better in position I think for collecting water than even Bala, good as Bala is. The water clouds get driven up those valleys and they drop down to the troughs. We are approaching a dry district whereas he has between us and his own position a wet one, and is more likely to receive a very much larger quantity of rainfall than we would.

2409. He states that his calculation of rainfall would be allowing 10 per cent. more than what is now found in the dryest seasons to be the rainfall for the supply of the Manchester Waterworks. You know quite well the Manchester districts, do you not?—Yes.

2410. Comparing those two districts, the Welsh district where he proposes to put his reservoirs and the Manchester reservoirs, do you think they are nearly similar?—I think the Welsh district is the better of the two—the wetter district.

2411. Should you as an engineer have any fear in making an open conduit for a considerable distance for carrying the water with a fall of say five or six inches to the mile, lined throughout with concrete and bricks?—I would perfer it covered for the reason which I stated; that would very much depend upon the character of the country which it was passing through.

2412. Assuming that it was so arranged that there would be no fear of water falling into it, should you be afraid that flowing as it naturally would at the rate of a mile and a quarter per hour, it would freeze in a very severe frost?—That is one of the difficulties which would attend it.

2413. Should you be afraid of an open mass of water which would be 10 feet deep, and perhaps 30 feet wide, and flowing at the rate of a mile and a quarter per hour, freezing?—I have known rivers flowing more rapidly than that frozen. I can remember passing over a river in the winter of 1812–13, which was navigable up to the point where I crossed it, and it was frozen over, and hundreds of people were skating upon it; what has been before, may be again.

2414. (*Col. Harness.*) The Thames was frozen in that year, was it not?—Yes. I am speaking of the Tay at Perth.

2415. (*Mr. Harrison.*) Still, that would not prevent the flow of the water underneath the ice?—No, it would not. Below the surface the water would continue to flow, but the danger would be in the breaking up.

2416. But as regards the mere actual supply it would not be so; in fact no river is constantly frozen over?—That is so.

2417. The actual supplying goes on just the same?—Yes, just so. Of course, when the height is taken from it they cannot deliver the same volume, but they can always deliver water.

2418. You would not be afraid of a body of water in this conduit flowing at the rate which I mentioned of a mile and a half an hour, as affecting the brick bottom?—Certainly not. Our experience is quite sufficient to warrant us in believing that with good workmanship and good material it would be perfectly safe.

2419. (*Col. Harness.*) What is the highest velocity that you would consider safe with a brick lining?—With a culvert such as that which Mr. Bateman proposes, I should not like to see a velocity very much greater than he proposes. It would be very apt to break.

2420. (*Mr. Harrison.*) Would you prefer where the water line is open to adopt the drainage plan of having overflows, or would you prefer one uniform surface?—I would rather have overflows.

2421. Still that is a mere matter of detail in construction?—Yes, take the fall between end and end and divide it, then you get the best fall.

2422. Has it ever occurred to you in the case of Liverpool that letting that town be dependent entirely upon its supply from one single source in time of rebellion or disturbances in the manufacturing districts they might without much difficulty cut off the supply from your town?—It is not a week old, in fact at this very moment I have watchmen upon the reservoirs night and day to prevent parties interfering with the water. I have placed men at all the junction valves through the town, and at all the mains communicating one with the other. But in a usual way we take all the precautions that we can so that the supply of water should not be interfered with.

2423. You do that in the case of Liverpool, but taking London with a probable increase of its population within a few years to 4,000,000, and assuming it to be dependent for its supply upon a single aqueduct, should you consider that to be an objection that would have much weight in your mind?—It would have some weight, for if you take away the supply of water from a city you take the city itself. Both ancient and modern history shows that generals have used that means of taking cities, by cutting off the supplies. The supply of water ought certainly to be so constructed, and so conducted, as that it would be in the least possible danger; but in passing over districts, such as is proposed to be done in any of the schemes which have been promoted for the supply of London, they would be all more or less subject to that danger; and I do not see how London can be supplied with water without some risk. It is impossible I think; you have not got the water immediately adjoining the city—it is not to be got from the chalk I think.

2424. Supposing that to be considered as an objection to be met, would it be met by retaining some of the existing pumping engines, so that they might at any time be used to supply in such a case?—All the pumping engines are near to London, they are not within London—at Thames Ditton for instance; the Lambeth Works and the Chelsea Works are close to London; and any hostile army approaching London would take those points which were most easily accessible, and which, when taken, would have the greatest effect upon the city; and no doubt a good general would turn his attention to that which would have the greatest effect upon the town he was about to take, and would cut off the supply.

2425. Where you have an aqueduct extending over a distance of 180 miles and odd, of course it would be much more easy for a body of men, not in the case of actual war, but people in a state of disaffection, in the same way as in Ireland, they have destroyed the telegraph, to take any point of such an aqueduct, half-a-dozen men, navvies, in the course of an hour's time would entirely destroy the supply to London?—No doubt it is open to that, but that is a very remote contingency I hope.

2426. It is not one that would at all influence your judgment in such a case as the supply of London?—I do not think it would, seeing the necessity that exists for such a supply. If it could be got without being exposed to such risks by all means bring it in that way which is not exposed; but when you cannot do that you must submit to inconvenience and to risk. If any invading army were able to effect a landing in this country and were to march as far inland as to be able to cut your aqueduct, and if they found their way up to the pumping stations in the neighbourhood of London, they would destroy them just as readily as they would destroy the aqueduct.

T. Duncan, Esq.

21 March 1867.

2427. Assume, not exactly an invading army, but a state of disaffection in the country, such as Fenianism or the rebellion amongst the manufacturing population, what would be your opinion?—I think that anything that Fenianism could do could easily be prevented; and supposing that they could do that they could not do a great deal, but of course it would be impossible to say what would be the effect of a revolution in the country.

2428. Still, in your mind, that objection which has been urged would not weigh with you as against the desire to supply London with pure water?—Certainly not. I would take the best supply that is possible to be obtained for London, and that which could be extended at will.

2429. Is your experience in favour of the corporate bodies in large towns having the entire charge of the waterworks for the supply of those towns?—Most decidedly.

2430. Do you find that they take more enlarged views of the subject than private companies?—I do. I am speaking now from a very slight knowledge of companies and from a very extended knowledge of corporations. But judging of the question from my point of view, considering the supply of water to any town to be a duty which ought to be discharged by the governing body of that town, and not by a trading company, I say that in my opinion the corporations of the various towns or other governing bodies ought to have the supply of water in their own hands. The question is so mixed up with the general health of a town that it is almost impossible to separate it from that view of the subject.

2431. (*Col. Harness.*) Do the corporation of Liverpool draw any part of its revenue from the water supply?—None; they pay their debts, keep the machinery in order, and pay their dividends for borrowed money.

2432. (*Chairman.*) Would you say the same thing as to gas?—No, it does not apply equally to gas. Although light is very essential, there are many ways of making light, yet we may have another way of making light, and people can make for themselves. They can burn candles if they do not choose to have gas. Certainly, with our present habits, we should not like to have recourse to another mode of lighting our streets, and where the gas can be obtained by corporations it might have to be administered as at Manchester, where they do administer the gas estate in the same way as they do the water estate. But yet it is not so essential to the welfare of a town; it does not interfere so much with the health of every individual as the supply of water does

2433. (*Mr. Harrison.*) Do you think that we might take it as a general proposition that in all those towns in England where corporations have undertaken to supply the water they are infinitely better supplied than they were before, and better supplied than towns that are supplied by private companies?—I think that the tendency is altogether in that direction. Corporations are more easily influenced than companies who have dividends to draw from their supply of water.

2434. (*Chairman.*) Do you raise your funds in Liverpool by means of rates?—We have a general rate, then we have a rent, and besides that we have a price per 1000 gallons for water supplied for trade.

2435. Is that rent a compulsory rent?—The rate is compulsory; the rent is not compulsory; and yet it is in another point of view, because if a house within the Borough is not supplied sufficiently with water, the medical officer can report to that effect and order it to be supplied.

2436. Have you a scale of charges adapted to the capacity of the house?—Yes we have. It is a percentage upon the rental.

2437. Has the corporation the power to say to A. and B. you shall have a supply of water, but if you decline to have the supply of water you shall pay a rental?—They do not pay a rental, but yet it is in this way; the rate which is 6*d.* in the pound, one half payable by the owner and the other half by the tenant is compulsory. If you have a private well of your own which yields you a sufficient supply of good water, the medical officer or the authorities would not interfere, but if, on the other hand, you attempt to supply yourself with water which is not in the opinion of the proper authority sufficiently good, he can report, and the corporation then have the power of laying on the water and levying the rent in addition to the rate. The rent at the present time is 6*d.* in the pound.

2438. Have they the power in default of the occupier paying, to charge the landlord?—No; in small property we compound with the landlords for the supply of the whole block of property, and then we make it a compulsory thing upon the landlord himself, just the same as the poors' rate.

2439. (*Sir B. Phillips.*) Have the corporation the power of rating every house to this water rate?—Yes, all property, whether warehouse, shop, or office.

2440. Have you, by your Act of Parliament, the power of creating a rate for the water supply?—Yes.

2441. By that Act have you the power of rating every house in the city of Liverpool to the water rate compulsorily?—To the water rate but not to the water rent.

2442. (*Chairman.*) What is the rate?—6*d.* in the pound upon the particular assessment.

2443. (*Sir B. Phillips.*) Is that paid by the tenant or by the landlord?—It is paid half and half.

2444. Supposing persons have wells in their houses and do not require the supply of the corporation, are they at liberty in any way to get away from the rating?—They cannot get away from the rating, from the rent they may, but not from the rate.

2445. In what way do you distinguish the rent from the rating. I take the rating to be 6*d.* in the pound upon the rental, or whatever it may be assessed at, and for that you undertake to supply a house with water? — There is an amazing quantity of water required for public purposes in a town, and whether you have a domestic supply or not the water is wanted for watering streets, flushing sewers, public fountains, and a variety of other purposes. The rate was levied by the Act of 1862 upon the whole town of Liverpool to pay for the water used for public purposes, and 6*d.* in the pound is, the rent for water used for domestic supply.

2446. Then, in fact, you have a double rate?—We have a rate and a rent, but the rent is not compulsory. I need not take the water for domestic supply if I do not choose, but I am bound to pay a rate for my house, or my warehouse, or my office.

2447. (*Mr. Harrison.*) The two together are about 1*s.* in the pound, I believe?—Yes; the rent is variable, the rate is fixed.

2448. (*Sir B. Phillips.*) The one is compulsory and the other is optional?—Yes.

2449. (*Chairman.*) Have you a copy of your Act?—Yes (*handing in the same*). The rating Act of 1862 deals with the question of compound shops and offices; that Act is quite peculiar, it differs from any other. We have several Acts, from 1847 downwards, but none of them affecting the question of rent and rate; there was quite a rebellion in the town upon the subject, and we had to go to Parliament to settle the question.

2450. (*Sir B. Phillips.*) What is the rateable value of property in Liverpool?—In 1866 it was 2,150,167*l.*

2451. (*Mr. Harrison.*) How long have the waterworks been in the hands of the corporation?—Since 1847, 20 years.

2452. (*Col. Harness.*) How do you draw the line between domestic use and trade use?—Where the water is simply used for the ordinary purposes of a household, for cooking, cleansing the house, waterclosets, baths, for the use of horses and carriages when they are used for family purposes, we consider that is domestic use, but where they use the water for any purposes of trade, as in the case of brewers, or where they have horses at hire, or use it for gardens,

such a use as that is not domestic. It is an arbitrary rate fixed by the council.

2453. (*Mr. Prestwich.*) You mentioned just now that the cost per mile, independent of the aqueducts, would be 13,000*l.*, but I see in this estimate, Appendix A., which you give, taking into consideration the cost of the aqueducts, the works at Bala, independently of the reservoirs, would cost 21,400*l.*?—That is the total cost per mile. It is 19,000*l.* per mile, independently of the reservoirs.

2454. With the reservoirs the cost would be 21,400*l.*?—I calculate the works to be done at Bala Lake at 100,000*l.*, and in the details I have taken a certain number of yards, 1,320 lineal yards of embankment, at 40*l.* a yard. There would be some little difficulty in securing the town of Bala and making permanent works, such as a large affair like this would require to be made. The byewash I have taken at 15,000*l.*, at 1*l.* per superficial yard, and the excavation and other works I have compared with some works which I have done elsewhere of a similar character. The bridge is 150 yards in length; I have taken that at 4,320*l.* Of the land I have taken 10 acres as the quantity required at the lake at 250*l.* an acre, as it is rather good land. I have put that at 2,500*l.*, the sluices 5,000*l.*, the extra width of tunnel at the entrances I have taken at 2,000*l.*, walling around the byewash and cutting 1,000*l.*, and the contingencies I have taken at 17,000*l.* over and above the contingency at 10 per cent., as it is a work which no one can very well tell what it will cost before it is gone into. Whatever other errors I might fall into, I was not disposed to fall into an error of estimate.

T. Duncan, Esq.
21 March 1867.

The witness withdrew.

Adjourned to Wednesday next at half-past 11 o'clock.

Wednesday, 27th March 1867.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND, K.G., IN THE CHAIR.

Sir JOHN THWAITES.
Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

THOMAS HAWKSLEY, Esq., examined.

T. Hawksley, Esq.
27 March 1867.

2455. (*Chairman.*) I believe you are a civil engineer?—Yes, I am.

2456. Are you a member of any societies?—Yes, I am a member of a good many societies; but principally a Vice-President of the Institution of Civil Engineers.

2457. We are quite aware that you are a great authority on all matters of water supply; would you be so good as to state to us your opinion on the best mode of supplying the metropolis with water?—That is a very wide question. I shall be happy to give the Commission any information in my power, but your Grace will understand I am sure that having no scheme of my own I can only answer such questions as may be put to me, and upon any questions which may be put to me I will give the best answers in my power.

2458. You are aware that there are two very large schemes which have been brought before the consideration of this Commission, one by Mr. Bateman for bringing water from the Welsh district, and another by Mr. Hemans and Mr. Hassard conjointly to bring water from the lake district?—Yes.

2459. Have you considered either of those plans?—I have perused the pamphlets and I have given such consideration to them as without a survey of the districts I was able to do.

2460. Would you give us your opinion as to the feasibility of carrying out a scheme as suggested by Mr. Bateman?—I presume I must take it that my answers are to be given upon the supposition that no opposition is offered hereafter by the parties in the district, for I am no judge of the opposition which might hereafter arise. No opposition of course can be made before a commission of this nature, and therefore I can only look upon it just as an engineer and suppose for a moment that no opposition arises. I know that there are very large interests down the river Severn, from its very head to the foot of the estuary, who will be greatly opposed, but unless the Commission wish to have any information upon the nature of those interests of course I will not touch upon them.

2461. If you are aware of any opposition that is likely to be made to the scheme, and if you are aware of the reasons which the parties have for their opposition, the Commission would be glad to hear whether you are in a position to tell us that that opposition is well founded or not?—I can give your Grace some information upon some of the questions which are likely to arise, such as the landowners' oppositions and oppositions which may arise from certain towns on the course of the river.

2462. (*Sir John Thwaites.*) When you speak of landowners do you mean the landowners on the gathering ground?—The landowners on and below the gathering ground, and also with regard to the opposition which is certain to arise in regard to, if I may use the word, the capturing of those flood waters from the estuary itself upon the question of scour. At the same time I would much rather, if your Grace will allow me, go into what of course I know more particularly about, and that is the engineering features of the scheme.

2463. We should be very glad to get all the information you can give us upon the engineering features, but of course the success or the feasibility of a scheme must depend very much upon all the opposition which it would be likely to meet with, and whether there was any good foundation for the dislike entertained to the scheme. Of course the last point to which you have alluded, namely, the capturing of the waters as interfering with the scour of the estuary, would be a very important feature in the case, because if the capture of the water were to such an extent as to interfere with the scour of the estuary, and so to be a very serious matter, of course that would go very much against the merits of the scheme?—No doubt. That is, however, a public question. With respect to the taking up of the flood waters generally, from my knowledge of the Severn, and I am tolerably intimate with it, having been constantly employed upon it for more than 20 years, I may say that it would be rather a benefit than otherwise, if considered apart from the difficulties which will arise in the minds of a great many private persons, and those persons will, I am aware, submit their cases to Parliament in a very strong form as to the policy of making reservoirs of such enormous magnitude upon the head of this great river. I am aware that that has provoked very much alarm, though of course as an engineer I am making reservoirs continually, and am by no means an alarmist myself; still where the project is of such an

T. Hawksley, Esq

27 March 1867.

enormous extent and magnitude as this project is, by which it is proposed to impound the waters of 120,000 or 130,000 acres, it must necessarily happen that the landowners on the course of the stream will be greatly alarmed, because if one of those reservoirs were by misfortune to burst I apprehend that, as in the case of the Sheffield reservoir and the Holmfirth reservoir, great destruction would ensue, and therefore I know that this project for impounding water is so large that many great proprietors on the course of the river will be opposed to it, and I know one or two cases in which a very strong opposition will be offered to any project of this nature.

2464. (*Sir J. Thwaites.*) With regard to the general benefit, is it a benefit to the river in mitigating the floods?—With regard to the diminution of the floods on the course of the river, providing a sufficient and proper amount of compensation is given out to sustain the summer flow the removal of those flood waters would be rather a benefit than otherwise in my estimation, but that is a question altogether different from that which occurs at the lower part of the river. Below the river at Tewkesbury the question assumes a different form; there the question of scour commences, and of course the larger the floods the better the scour, and, inasmuch as the estuary of the river Severn is a sandy and oozy estuary, it is very necessary that those floods should be maintained unless other works are made to prevent the deteriorating effect of the removal of the flood waters. It is very necessary that those floods should be maintained in order to carry that oozy deposit out to sea. The entrance now to Gloucester and to the ports below Gloucester is very indifferent, and I may say even precarious, and the maintenance of the channel is not entirely due to the recession of the tidal water, but to the recession of the tidal water, augmented both in velocity and quantity by the mountain floods.

2465. (*Chairman.*) Now, will you give us your opinion of Mr. Bateman's scheme in an engineering point of view. Are you acquainted at all with the rainfall in that district of country?—Not specially in that country, nor am I aware that anybody is. I believe that there have been no sufficient gauges established in that country to determine the average amount of rainfall, but I know a great deal of the rainfall in analogous districts, and I estimate it myself at 45 inches over the whole surface. There are many parts of that district where the rainfall will be much larger, but the areas upon which that larger rainfall obtains will be small, and the average of the whole upon which it would be safe to depend does not in my opinion exceed 45 inches.

2466. Do you believe that an average of 45 inches over the whole surface would be sufficient to give a supply to London?—No, not on the scale which is proposed.

2467. What do you conceive would be the supply necessary for London?—The present supply to London averages a little more than 90,000,000 gallons per diem. The quantity used in the month of largest consumption was 105,000,000 gallons nominally, but that quantity is ascertained from the displacement of the pumps, and from that must be taken for leakage and other losses through the working barrels and other parts of the work quite 10 per cent., so that the actual distribution would probably be about 94,000,000 or 95,000,000 gallons per day in the month of largest consumption.

2468. What is that month?—It varies. July in London is about the month of largest consumption; in other places it is generally about August, but the London population, at least the West End population, goes away about the middle of July, and of course the consumption is diminished by the operation of that cause.

2469. In order to furnish that supply to London, what amount of rainfall would you consider to be necessary?—I should first explain that the 45 inches of rain is only the quantity which on an average descends from the heavens, and that quantity is subject to two deductions. In the first place, we know as a matter of absolute fact that we cannot by any system of reservoirs which it is practicable to construct (I will not say with a reasonable but with a large amount of capital) deal with more than the average of three consecutive years of minimum fall. We know as a matter of experience—and this important fact is verified by large and long-continued rain tables—that in those three years the average fall of rain is almost precisely one-sixth part less than the general average, and I could refer the Commission to any number of long-continued rain tables to establish that fact; but we know also as engineers that practically that is the case. If we take from the 45 inches a sixth of that quantity, that will be $7\frac{1}{2}$ inches, and that would leave $37\frac{1}{2}$ inches as the quantity of rainfall due to the three minimum years. Then from that we have to take the evaporation. Now, the evaporation over a district like that, part of which is lowland and part of which is highland, will be about $13\frac{1}{2}$ inches, and if that be deducted there is the residual quantity of 24 inches, and that may be deemed to be the available quantity. That is the way in which we now make all our calculations for undertakings of this kind. I am not shifting or moving the calculation in any way. This system has been tested by actual results in a great many cases, and is known to be as accurate as anything dependent upon the eventualities of the seasons can possibly be. It is as near to the truth as we can in practice obtain anything.

2470. You stated that 45 inches was the average rainfall over the whole surface from a comparison with districts of a similar character, will you tell us what those districts are?—In the districts which I mentioned of a similar character where rain gauges have been established, at Rivington for instance, on the Liverpool waterworks, we know that to be the case, and generally in the hilly districts of Lancashire which are certainly as near to the Irish Channel as this Welsh district is, and where the rainfall is certainly as great. And I may mention a very important fact within my own knowledge with regard to the lake district from which extensive deductions have, I think, been made in this case. I am speaking now of the Cumberland and Westmoreland lake district. In that case the rain gauge returns lead to conclusions, which according to my view, are not all well founded. I had the honour of making the waterworks of Whitehaven, and I have been considerably concerned in the lake districts, and I was intimately acquainted with Dr. Miller who has been referred to in this case, and who instituted those observations which have been brought into the evidence which has been laid before this Commission; but the object of Dr. Miller, who was simply a philosophical investigator, was not to ascertain the mean rainfall in the lake district, but to ascertain the most extraordinary and abnormal rainfalls, and when those gauges were put up they were put up in very peculiar situations, where it was known that large rainfalls obtained in order to measure them as a matter of science, and after they were put up they were moved half a mile, a quarter of a mile, a mile, and so on with a view of obtaining the largest possible results, and those results were obtained, and consequently that circumstance proves that if a square mile receives that large amount of rainfall it ought not to enter into the consideration of a question like this. I believe it is very possible that the gentlemen who may have used those rain tables are not acquainted with all these facts; these things get into books and then they become relied upon as good and valuable data. They are good and valuable for the purposes for which they were intended, but not for this purpose.

2471. Are we to gather from you that you consider that there would not be a sufficient quantity of rainfall in the district proposed to be used by Mr. Bateman to obtain the necessary supply for London?—No; what I say is this—leaving it entirely to the Commissioners to use the information which I have the honour of placing before them in such way as they like, that to the best of my knowledge and belief not

more than 24 inches could be relied upon as the available, collectable, and usable rainfall of the Welsh district. I may mention to the Commission this fact, that when reservoirs, however large, are made, they become filled, and when they become filled the rain still continues to descend, and that water simply goes over the bye-washes, and is lost. Now the quantity of water so lost is represented by the one sixth which I have taken into account, because as the reservoirs must be made to supply during those three dry years, at the average rainfall during those three dry years, they cannot possibly receive the accumulated waters of the wet years. I have here some important diagrams not made at all with reference to this matter which will illustrate my meaning.

2472. Can you put them in so that they may be appended to the report?—Yes, if your Grace pleases. They will require a little explanation, as they were made for my own use only in my investigation as an engineer, and for the purpose of founding upon them certain formulæ for my own use and practice. This diagram (*producing the same*) represents the rainfall of a wet district, in every year from 1831 to 1865.

2473. To what district does that diagram refer?—This is the Bolton district. I have also another diagram of a Scotch district, the Greenock district (*producing the same*). The red line represents the line of average rainfall. You will observe one case in which a large quantity of water was received above the average in the year 1832. I may mention also that you see the excesses of water at different places above the average and also see the defects marked. In order to have made the excess of the year 1832 available we must have kept a portion of that water till the year when you observe that there was the lowest quantity, and it could not have balanced itself for 18 successive years. In one case you will observe there is a hole, so to speak, of rainfall, in which a little portion might be put, and we may therefore write off a little of the top. Then we go on for two years and we come to another excess; we have nowhere to put that excess. Then in the year following we come to another deficiency. We might nearly put that excess into the former cavity, so to speak. The next year the line of average rainfall coincides very nearly with the actual quantity of rain. Then there are two years of defect, and we can put a little more of the excess into that cavity. Then there comes a year of excess again, and that would very nearly fill the rest of the hollow space, leaving still unused, supposing it could be kept, a portion of the first excess. And so we go on, balancing one against the other until at last we find that it would be 18 years before this surplus rain could be made useful, if we acted upon the principle of making the average rainfall available. We find that in point of fact to be a perfect impossibility, because the reservoirs that would take up that larger quantity of water which is seen in 1831 and 1832, and again in 1852 and 1860, and so on, would be so enormously large (and we can perfectly calculate them) that they could not practically be made, and they never are made.

2474. Will you state to the Commission what you consider now and for a certain number of years would be the supply that ought to be obtained for London?—That depends entirely upon the principle upon which the supply is to be given. The present maximum supply of any month in the last year was about 95,000,000 or 96,000,000 gallons per day of actual water, but the return made upon the principle I have mentioned gives about 105,000,000 gallons per day for the average of the month. When we are speaking of gravitation supplies the actual quantity and not the quantity measured by the displacement of the pumps is taken into account, and we must consider it to be 95,000,000 or 96,000,000 per diem.

2475. Do you think that that is sufficient?—Undoubtedly that is much more than it ought to be if the fittings in the houses were in a proper condition in London. Although the water is given for only a short period of the day the fittings are in such an imperfect condition that the waste is enormous.

2476. (*Sir J. Thwaites.*) Do I rightly understand that, having regard to the whole of the gathering ground suggested by Mr. Bateman, you are of opinion that there would be an average rainfall of 45 inches?—Yes, I think so. But I consider that nobody is in a position at present to pronounce what the rainfall of that district is. I am not myself, and I do not put it as if I were.

2477. I understand from you that you deduct one-sixth, is that for absorption?—No; that is for the loss of water which is inevitable in works of this kind, the loss occasioned by floods going over the waste weirs, and the impossibility of making reservoirs to deal with the wet years.

2478. That would reduce it, would it not, to 37½ inches?—Yes.

2479. Then you allow for evaporation, or is that included in the absorption?—No; we have now got to the yield of three consecutive dry years. I may mention to the Commission by way of explanation that in all cases the extreme dry year is as nearly as possible one-third less than the average, and that the extreme wet year is in all cases as nearly as possible one-third more that the average. Then by means of very large reservoirs (and I will give you the data which I employed for determining the sizes of reservoirs) we can reduce that difference from one-third to one-sixth. But then we cannot deal with the remaining sixth, because the reservoirs would be so enormous, for we should have to impound in them the water of those excessively wet years, and that it is quite impossible to do. I can give a great many instances of the way in which I deal with this subject, and the way in which I have come to this conclusion is this: I have learned experience from a long course of failures; I have had my failures like other people, and I have learned from other people's failures as well as profited by my own; I prick the facts off on a diagram, and then pass a curve through the prick marks, and then I find an equation to the curve; and that gives me a rule which I can employ usefully in all cases, and by continual correction, by new facts, we get gradually nearer and nearer to accurate results.

2480. You stated, did you not, that you allowed from the 37½ inches 13½ inches for evaporation?—Yes; 13½ inches.

2481. That would give you an available rainfall of 24 inches?—Yes, upon which you might in my opinion safely rely providing your reservoirs were made large enough to deal with that quantity.

2482. (*Chairman.*) What sized reservoirs should you think would be large enough to deal with that quantity?—The reservoirs to deal with that quantity should be of a magnitude to store 170 days supply.

2483. What does Mr. Bateman propose?—Mr. Bateman says 120 days, that should be about 170 days on my calculation.

2484. (*Mr. Harrison.*) I think you agree that 24 inches are available also for the supply of mills and everything?—Yes, of course. The quantity to be given in compensation is to be taken off before you get to the distributable quantity, but first of all I was dealing with the available rainfall.

2485. (*Chairman.*) 24 inches is what you have to deal with to supply everything, rivers, mills, and London?—Yes.

2486. (*Col. Harness.*) Your reservoirs must be considered, must they not, with reference to compensation just as much as to the water for the consumption of London?—Yes, certainly. In fact there is no difference between the two cases. You simply let the water off by two different pipes, and if there were no compensation it would all come to London; but if there is compensation then one part goes down the rivers and the other part comes to London, but it is all a mixed quantity to be agglomerated in a consideration of this kind.

2487. (*Chairman.*) Do you consider that there

T. Hawksley, Esq.

27 March 1867.

would be any difficulty in making reservoirs large enough to contain that supply?—I have not an idea upon that subject because I have not been down to the district to examine it. I may say that supposing so large a quantity as 300,000,000 gallons to be necessary, the area of the watershed must according to my view be largely increased. If Mr. Bateman, for instance, has taken 36 inches as being available while I take 24 inches his watershed which I think is somewhere about 130,000 acres must be increased exactly one-half, and that would require a watershed of 200,000 acres.

2488. (*Mr. Harrison.*) Putting aside in the first place all opposition to the scheme, and putting also aside the question of cost for the moment, and looking at it as a mere physical work, do you consider that it would be practicable in an engineering point of view to bring the waters from Wales to London by gravitation so as to deliver them as is proposed by Mr. Bateman at a height of 250 feet above datum?—Perfectly practicable in an engineering point of view.

2489. I presume that not having examined the route which it is proposed to take or not having had an opportunity of examining the site of those reservoirs, you have no data to enable you to give any opinion as to what their cost might be?—I have not any data from observation, but I may mention this that if the quantity of 220,000,000 gallons for London, plus one-third of that quantity for compensation making together 300,000,000 gallons per diem, is to be dealt with the reservoirs according to my view must contain more than 8,000,000,000 cubic feet, and that amount of storage is about 1½ times as much as I think Mr. Bateman has calculated upon. At the same time I think it is fair to mention that I do not know of any necessity existing or probable for bringing so vast a quantity of water to London. The average quantity of water used in London is not more than 85,000,000 gallons per diem.

2490. (*Mr. Prestwich.*) How much is that per head?—That would be as nearly as possible 28 gallons per head. That is on the average of the entire year. I believe that that quantity might be greatly reduced if a better system of fair and proper supervision were introduced by the water companies. The water companies now take no charge of the water after it has left the ferrule of their main pipes, and the waste in houses, consequent upon having imperfect fittings, is very great indeed. In many cases, thousands, nay, I might almost say scores of thousands of cases, the water is supplied into butts and other places where there is not even a ball cock to arrest the waste. Everyone of those receptacles is provided with a waste pipe, and of course when it becomes filled, the water does not overflow except by the waste pipe, it does not annoy anybody, and nobody cares anything about it. I consider that the system of the London water companies, with regard to the care of the water, is exceedingly defective indeed. I have not a word to say for their system.

2491. What do you consider would be a sufficient supply per head?—For all the purposes of London, but that includes many things which are not at present very much in use, I should consider that 25 gallons per head would be an extreme supply. Taking the vast size of the place into account, and the magnitude of the population, there are no great number of trades using water; the trade consumption of London, although considerable on the whole, is a very small proportion of the quantity of water which is distributed, whereas in many towns in the country, where the constant supply has been introduced, and where the trade consumption is large, the average quantity of water delivered is under 20 gallons per head. I am speaking now of cases where there is a good and useful inspection, yet with nothing that is oppressive or invidious.

2492. (*Colonel Harness.*) Can you separate the proportion which is used for domestic purposes, as house supply, from the remainder that is distributed?—We know pretty well that the quantity used for domestic purposes is about 12 or 13 gallons per head per diem. In certain parts of London it will considerably exceed that, as, for instance, in the west-end it is much more, because people have baths in their houses, which are a cause of a very considerable consumption of water, but, then again, that is compensated by the comparatively very small quantity of water which is taken at the east-end of London; certainly there are very few houses in which there is anything like a consumption of 25 gallons.

2493. Then would 13 gallons per head be the average between the two?—No, that would be the average of the whole, not the average between them. I should think there are houses in London, indeed many at the west-end, where 20 or 25 gallons per head, or even 30, would not be too much.

2494. (*Mr. Prestwich.*) Have any experiments been made in any public establishment to ascertain the exact quantity of water, individually, for a large number of people?—Yes, it has been done in a great many cases, and for my own information I put on a gauge at my own house. I wanted to ascertain how much my water cost me per 1,000 gallons, and to compare it with the whole quantity of water in London.

2495. (*Sir J. Thwaites.*) What was the result in your own case?—In my own case the result was, that the water cost me almost 2*s.* per 1,000 gallons. I take great care of the water in my own house, not to allow it to be used unnecessarily.

2496. What quantity per head do you calculate for the inmates?—I forget the precise quantity; I took my experiments in relation to the cost at the time; the actual amount used was not more than 10 or 12 gallons, excluding baths.

2497. That did not include the stable I presume?—No, that is separately supplied.

2498. I understand you to state that 25 gallons in London would be a sufficient quantity per head under proper supervision, including trade and all other purposes?—Yes, including everything, undoubtedly.

2499. (*Mr. Prestwich.*) Have not some experiments been made at some of the hospitals with regard to the quantity per head used?—I do not know, but I have made experiments in former years both at hospitals and lunatic asylums, and generally the consumption is very excessive. There is a large waste, and besides that there is an abnormal quantity of water used for baths in many of those establishments, and the water-closets are badly fitted up; in these the water runs to waste almost continually.

2500. (*Mr. Harrison.*) In your experience have you found that the quantity of water consumed per head has been increasing during the last 10 or 20 years?—No doubt. It has been increasing from the introduction in part of more luxurious habits, and in part of better habits. There are amongst large populations much greater numbers of waterclosets than there were formerly, and there is also a much greater number of baths. The waterclosets if properly fitted and arranged may be kept perfectly sweet with a very moderate quantity of water, but the consumption by baths is very large; very few baths indeed take less than 50 gallons at each time they are used, and a great many of them take more.

2501. Is it at all contemplated that the water companies should exercise such a supervision under any powers to be granted to them?—At present it is not a matter of any very great importance to them, because in some degree they check the waste by putting the water on for only a short period; that to a certain extent checks the waste, although it does not check it entirely; but then they take, I daresay, this view: that if they had a sufficient inspection it would be costly, and they contrast the cost of the inspection with the cost of the coals for pumping the waste, and they have come I believe to the conclusion that they would not gain much at present by instituting a more careful inspection.

2502. Supposing London were supplied by gravitation and with a constant supply, what should you consider safe as the least amount to calculate upon per

head for all purposes?—In my view 25 gallons would be safe; but if you extended it to 30 gallons I think there is no doubt whatever that that would be a superabundant quantity. Of course you must add to the present population and that is a very difficult question because it is quite impossible to take it that London should increase at the rate it has recently done; we know indeed by the census tables of this kingdom as well as of others that the rate of increase is declining. In all countries the rate of increase attains a certain maximum and after that it declines. Put it as it was in England at the period of the greatest increase; the increase I think was a little over 2 per cent. per annum throughout the kingdom in general. Then it declines and it will go down to $1\frac{3}{4}$ per cent. Then in future periods it will be $1\frac{1}{2}$ per cent., and so on till it comes down to a more moderate rate of increase. In England we have had a wonderful stimulus by the inventions which have been made; the introduction of the steam engine and railways in particular and the enormous development of our manufacturing power contributed for a certain period to a most rapid increase of the population, but the increase will not, in my opinion, continue at the same rate; nor is the supposition warranted by the statistical facts gathered in England itself and in other countries as well.

2503. Assuming that your view is correct, and that instead of 36 inches only 24 inches would be available, that would merely involve the question of the additional area to be included and consequently of additional cost in the reservoirs upon that area?—Certainly. That is supposing that the ground in the neighbourhood in which the reservoirs would have to be formed (which I do not know to be) is of the proper height, then it is only the question of cost; and I may remark that if smaller quantities of water are wanted than have been calculated upon in this great scheme of course that must be taken into account too the other way.

2504. In your experience of waterworks all over the kingdom, has your attention been specially directed to the quality of water which is most suitable, all things considered, for a large population?—That depends very much upon the habits of the population and their necessities with regard to trade and manufacturing purposes. In the north of England, in all the coal districts, it is very important, because all the great manufactures of the country are always concentrated where coal is, and it is very important that they should have soft water; and the question of the quality of the water in other respects becomes a minor one. In the metropolis it is very necessary that the water should be a white water, perfectly clear and perfectly free from colour.

2505. (*Sir J. Thwaites.*) Why should it be white in the metropolis?—Because it is so disagreeable and so contrary to the taste of the people to have coloured water; they do not like tinted water.

2506. (*Chairman.*) Is soft water necessarily tinted water?—Soft water is almost necessarily tinted water, and is so with very few exceptions. The soft water generally comes from moors and from mountain districts very elevated upon which there is a large quantity of peat growing, and it is almost impossible to prevent that water acquiring a stain more or less deep.

2507. In those districts in which there is a great quantity of peat, except in times of flood, is not the water a very good colour?—It is, but then it is the flood water which is the significant portion of the whole supply. The ordinary flow of the stream is trivial in comparison with the quantity of water that is carried into the reservoirs during floods. I will give this as an illustration. We know by actual admeasurements upon many works, but I will take the Liverpool Waterworks as a very good instance in point, that the floods are 300 times the minimum quantity of the flow of the stream—that is to say, the daily dry weather quantity of July and August is not more than $\frac{1}{300}$th part of what a flood will bring down in a day, and that is quite a common incident to all those mountain streams. The average of the period of wet weather gives a larger quantity than the minimum of which I have spoken by way of illustration, but the consequence is that if you get, say 100 times the volume of brown water to one part of white water, the white water has very little effect in removing the tint.

2508. (*Mr. Harrison.*) Those are extreme points?—Yes. I have put them so, and only by way of illustration.

2509. Take the water of Manchester as we have seen it in the Queen's Hotel, put into bottles and poured into a glass, do you call that white water?—The Manchester water is very often untinted, but it is also frequently tinted; but the fact is, with regard to Manchester, that a separation to a certain limited extent takes place between the white and the brown water, the compensation water being given out of the reservoirs which are not used for the supply of the town, although they may be used for that purpose.

2510. That is the same plan, is it not, which Mr. Bateman has explained to the Commission that he proposes to adopt in his scheme in Wales, so far as it is available?—Yes, so far as it is available, but it is not generally possible to adopt that plan to any great extent.

2511. Going further into the question of the quality of water, do I correctly gather that your view is that, although in the coal and manufacturing districts soft water is an important matter, you do not look upon it as such in the case of London for instance?—Not importantly so; but I must observe that the harder waters divide themselves into two classes, namely, those waters the hardness of which arises from the presence of carbonates and those waters the hardness of which arises from the presence of sulphates. If the hardness of the London waters arose from the presence of sulphates instead of carbonates, as is the case in many parts of the kingdom, I should consider them very unsuitable; the carbonates, however, are not only innoxious in themselves; but as regards many of the purposes for which water is wanted, they are thrown down when it is heated, and the water then becomes exceedingly soft. Now the London water is very soft water, and all chalk waters are so after they are boiled; for manufacturing and many other purposes water is boiled, and also for many domestic purposes.

2512. To put it in a practical way, if you had the choice in the supply of London with water of the degree of hardness which is now supplied hardened by carbonates, and you had the choice also of taking soft water, such as we will say is supplied to Manchester, to which would you give the preference?—If I could get the water tolerably free from stain I should use the soft water, but if I could not I should most certainly, in the case of the metropolis, use the white water in preference to the brown water.

2513. (*Mr. Prestwich.*) When you speak of the importance of soft water for the coal districts, that is, with reference, is it not to the use of water in steam engines?—No, I did not put it simply with regard to the use of water in the coal districts, but what I said was this, that all our great manufactories using water are located in the coal districts, because, of course, of the economy, which attends their being in the immediate neighbourhood of collieries, it is not because of the collieries, but because of the manufactories. The bleaching, dyeing, calico printing, and a great number of other important manufactures, are all established in this kingdom upon or close to the coal formation, and it is very important to them to have very soft water. It is not merely nor altogether largely, though no doubt very importantly, in an economical point of view that they require soft water as a means of saving soap. That, of course, enters into their calculations as an economical question, but generally soft water gives a peculiar character to the fabrics. Take for instance the wool district—wool which is dressed with soft

T. Hawksley, Esq.

27 March 1867.

water and wool which is dressed with hard water feel quite different. Wool which is dressed with soft water feels like silk, whereas wool that is dressed with hard water feels harsh and unpleasant—they are easily distinguishable. Therefore, all the cloth manufacturers prefer to have soft water.

2514. That is very variable, is it not, with regard to different manufactories; some may prefer soft water, and others may prefer water not so soft?—I do not know any case excepting in the manufacture of beer in which hard water is preferred to soft water. In the manufacture of beer hard water is much better than soft water, especially hard water in which the hardness is occasioned by the presence of sulphates, because that water does not take up the extractive matter from the malt, and, therefore, you get a clear bright amber-coloured beer, whereas, in the other case, you get a thick, glutinous, and dark-coloured beer.

2515. Do you know anything of its value in dyeing?—Yes, in dyeing it is very important, not only that the water should be soft, but that certain things which are very frequently present in hard water should be absent—for instance the salts of magnesia—it is very important that they should not be present in any considerable quantity. It so happens that as regards the Thames water there are neither sulphates nor any important quantity of the salts of magnesia which are generally to be met with in the lias and dolomitic districts of England.

2516. (*Sir B. Phillips.*) I understand you to say that the present consumption of water per diem in the metropolis is something like 95,000,000 gallons?—The maximum consumption is about 95,000,00 gallons, the average consumption is about 85,000,000.

2517. Could the existing companies supply a much larger quantity if it were necessary?—Yes.

2518. Have you any idea as to what quantity they could supply with their present resources?—They can supply 100,000,000 gallons I believe from the Thames, and of course there is much more than 100,000,000 gallons in the Thames. Then the New River Company's resources are a little over 30,000,000, and the East London Company has as nearly as possible 20,000,000 gallons, but it is very difficult to say what the Kent Company can derive from their wells; they have wells in two or three positions, and I suppose they might derive perhaps 10,000,000 gallons, it is impossible to say exactly, but we might put that as the maximum.

2519. (*Sir J. Thwaites.*) Do they take any water from the Ravensbourne now?—No.

2520. (*Sir B. Phillips.*) Those quantities together would make about 160,000,000 gallons?—Yes, of course the London companies can get a very much larger quantity of water by obtaining further powers to pump from the Thames, and there are also large districts of chalk where an immense quantity of water might be obtained. That would be subject to compensation of course. Take the Colne for instance, the Colne is a remarkably fine river; it is now affected to a considerable extent by paperworks, but if the London companies took the Colne and compensated the parties interested in the Colne they would get a minimum additional quantity of about 50,000,000 gallons a day.

2521. (*Col. Harness.*) Are we to understand you that at the present time the existing companies could give an additional supply of 160,000,000 gallons a day without having to go to Parliament for further powers?—No, 160,000,000 gallons is the total quantity.

2522. You mean that it could be increased up to 160,000,000 gallons?—They have the power in their own hands of giving that quantity.

2523. And you think the present average supply is 85,000,000?—Yes.

2524. Without going to Parliament and without being subject to claims for compensation?—Yes.

2525. (*Sir B. Phillips.*) You have given some attention to Mr. Bateman's pamphlet; have you seen Mr. Bateman's figures and his estimate of the cost?—I have. I do not presume to imagine that Mr. Bateman put it as exact, but I have no doubt he has done as I should do if I had a similar project. He has done his best with it; of course he lumps in the rights of the parties all the way through the country where this conduit would come winding through it. All those would have to be considered in detail if this were a Parliamentary project instead of being a popular exposition of an engineering scheme.

2526. I think you say that, looking at it simply as an engineering project, apart from all other considerations, Mr. Bateman's scheme is quite practicable?—I think so, subject, of course, to what I have said with regard to the reservoirs. I have not examined the country, and I therefore cannot offer an opinion upon that point.

2527. Looking at the security of a large city like London, with its growing population, do you think that it would be safe to rely for an exclusive supply of water upon a source so distant as the scheme propounded by Mr. Bateman?—No, I look upon that as being one of the most serious objections, not only to Mr. Bateman's scheme, but to anybody's scheme for bringing water from so great a distance. My attention was called to this subject many years ago in relation to quite a different project, and therefore I may state at once what my views are. In the first place, admitting that you could be sure in all seasons of getting a supply for London of the calculated quantity, there would arise the difficulty of ensuring its arrival here. We know that when water proceeds along channels with a small declivity, in frosty weather, particularly when snow is falling, it gets into a state of semi-congelation, and refuses practically to travel at all; it either moves in the slowest possible way or it will not travel. That, to my mind, is a great difficulty, and I do not see a way of overcoming it unless by means of tunnels or pipes, the cost of which would be enormous, or unless some other means which I do not know of were adopted to prevent that effect being produced. Then another great objection, and I may say that this objection has been practically raised by foreign Governments to schemes of my own under similar circumstances, is this, that those waters might be easily interrupted. I have not much fear of a foreign invasion, although such a thing is possible, but the most probable event is that the water might be stopped or let off in troublous times; it is perfectly impossible to protect a line of that length, and the water might be let out at a period of excitement, such as has occurred several times within my memory—for instance, in 1831 and 1848, and at various other periods, and I think it would be a very great calamity if such a thing happened. I should have very great doubt indeed as to the advisability of bringing water that great distance in channels of the kind which have been proposed. As an engineer, I can say that I believe it to be perfectly practicable, but, as a legislator, if I were one, I should entertain great objection to it.

2528. (*Mr. Harrison.*) In such a case as that, assuming that such a scheme were ever carried out, it could only be done by the whole of the existing water companies being really placed under one management, and could that objection be met by retaining a portion of the pumping engines of the present system to meet cases of emergency like that?—That, of course, to some extent might be so, but I do not think, unless you were quite willing to incur a very considerable annual expense in addition to the ordinary expenses of an undertaking of this kind, that it would be at all feasible or desirable to keep up the present establishments. It must be borne in mind that there is something like 12,000 horse power used in the London waterworks.

2529. You are aware that in Mr. Bateman's scheme he shadows forth the idea that all the existing water companies would be either amalgamated or bought up, or something done with them, so as to unite them into one, and that a large amount of saving would take place from, first of all the saving of pumping, and again from the sale of what would become superfluous property. If that were to do you still say that that

saving would not be realized if the engines were to be retained to meet such an emergency as that which you contemplate?—No; but I can give you some information upon that subject. Let it be assumed that this work increased in the proper proportion—could be executed and all compensations paid and everybody satisfied along the line for something like 10,000,000*l.* or 12,000,000*l.* I do not look upon that *per se*, though it is a large expense as a formidable one; but the next thing is this:—The present net revenue of the water companies is, as nearly as possible, 500,000*l.*, and at the time when this work could be brought into operation it will exceed that; but supposing that those companies could be bought at only 20 years' purchase that would amount to 10,000,000*l.* Then supposing you add say 11,000,000*l.* for works, that would be 21,000,000*l.* Then you add to that that it is impossible to have a constant supply (and it is upon the doctrine of a constant supply that this project I apprehend hangs) without reforming all the fittings and service pipes and so on in London, the cost of which would be, as nearly as I can estimate, and I mention that my estimate has been formed for other purposes, 8*l.* a house, and that would bring out a sum of about 3,000,000*l.* Then we have to add to that again the cost, which would be considerable, of rearranging the present system of piping, because it certainly is not adapted for the new project, and there would be a very considerable amount of alteration required. If you put all that at 5,000,000*l.* that would bring it up to 26,000,000*l.*, and that is, I believe, the very smallest sum for which it would be possible to carry out this project.

2530. (*Sir John Thwaites.*) When you speak of 20 years' purchase is that 20 years' purchase on a valuation or 20 years' purchase on the nominal capital of the company?—20 years' purchase on the net revenue. The way in which these purchases are made, and there are many of them, is this:—First of all, the net revenue is arrived at, then that net revenue is in general multiplied by 20, and in some cases by 22 years' purchase. That gives you a certain capital. Then you have to ascertain whether the property is freehold, and if it is not freehold you make a deduction from that for purchasing up the reserved interests. Then you look to the works and you ascertain whether they are in good and efficient working condition—not whether they are new, but whether they are capable of carrying on the supply permanently upon which the net revenue is obtained—and if you find that they are not in that state but are dilapidated, you ascertain the amount of dilapidation and deduct that. In the next place you inquire whether the works are more than capable of performing the service upon which the net revenue has arisen, and if they are more than capable of doing that you ascertain what the value of the additional capability is, and you add for that, and the total of those amounts forms the sum which is to be given, with the exception of one consideration. You have then to ascertain what is the prospective value, whether the interests of the company prospectively are improving, or whether they are only at a standstill. They are not necessarily improving, although their income may be increasing, and their net revenue may be increasing, if they have to put in a proportionate amount of capital; but if a company has made 6 per cent. one year and in the next by the natural increase of its business, without making any more works they get 6½ per cent., then you must look to that, because that is an undeveloped portion of their interest, and then, according to rules which are very well understood, you add for that prospective interest. Then the result is the net sum which is to be given. After that, of course, comes the consideration as to whether that sum is to be commuted into an annual payment, or whether it is to be paid in gross. But that is the uniform mode, and it is a just one, in which those things are done.

2531. It is a mode of ascertaining, and no doubt it is a simple question the number of year's purchase, but you are putting the revenue of the company upon the same footing as you would put a freehold?—Yes, and that is the principle uniformly adopted. I know no instance in all the great valuations where that has not been done. For instance, it was done in the case of the Liverpool valuation, which is the largest that I am aware of. There is one nearly as large at Manchester, that proceeds in a somewhat different way; but at Liverpool, where Mr. Robert Stephenson was appointed the arbitrator, and in a great many other cases, that system was pursued, and pursued under the advice of counsel, and it has never been questioned.

2532. I am not speaking about the system, I am speaking about the number of year's purchase?—I am speaking also about the number of year's purchase, and if you will look at the rate at which in general waterworks shares are sold in this kingdom, you will find that as a rule the rate at which they are sold exceeds 20 years' purchase of the dividends.

2533. Of course they are subject to competition. Take, for instance, the water supply of London; supposing Mr. Bateman were to bring his water from the district which he suggests, and set up a separate establishment, what then?—There are two observations to be made upon that. In the first place, it may be true that they are subject to competition, but no competition can be established except under the authority of Parliament, and that does not affect the value of the property. In the next place, supposing the property to be transferred under the authority of Parliament, that is to say, supposing an Act were passed by Parliament for transferring those works, it is invariably the practice that the case of competition is by that Act put out of the question; you cannot take it into account, and it would not be admitted in any case at all that you could take the value of competition into account where an arbitration is to take place to determine the value of property, because it is always the value of the property as it exists. The purchaser goes in upon the principle of there being no competition.

2534. (*Mr. Harrison.*) With regard to the question of freezing, what is the actual state of the case now in the New River?—In the New River they have had the greatest possible difficulty on many occasions to keep the town supplied, and that is only a short and a small work, a work which at this period, I suppose, brings not much more than 23,000,000 gallons a day; but for bringing about 23,000,000 gallons a day the New River Company have very considerable reservoirs, none that are worthy of being taken into account in a question of this kind, but by the aid of those considerable reservoirs they do manage with extreme difficulty to maintain their supply during frosty weather.

2535. The New River is for many miles a continuous open conduit, is it not?—It is. I suppose now there are about 18 miles of it open, it has been very much altered from what it formerly was, and very much shortened.

2536. Mr. Bateman in his evidence before this Commission, has stated that his view upon that point is this, that he would make his conduit a series of tunnels and open cuttings, and being where it is an open cutting something like 30 feet wide and 10 feet deep, and with a velocity of about a mile and a quarter per hour, he thought that the temperature of the water coming out of those tunnels and passing over a short distance of open cutting would prevent its freezing?—I believe that if it were possible to put it in short lengths, half in tunnel and half out of tunnel, that result might possibly be obtained, but that would be problematical, because the great difficulty is when the snow is falling. When snow falls into the water it does not melt to the then temperature of the water, but gets into a sort of gluey form, which is very well known, and is a very remarkable obstruction, and then the water proceeds either not at all or in a glacier fashion, very tardily. Therefore it is in the open part of the cuttings where the objection would obtain. But I apprehend it would be quite impossible to make an adjustment of that kind; of course there would be

T. Hawksley, Esq.

27 March 1867.

many tunnels upon the line, but I suppose there would be 20 or 30 miles at a time of open cutting, and it would be natural to me to suppose so, because the line as I understand would follow in some part of its path the course of the Grand Junction Canal, and we all know that the Grand Junction Canal is open for a very much greater length.

2537. But you are aware that the Grand Junction Canal of course takes all the windings of the valley along its course?—So I suppose would this conduit, because if it did not you must substitute pipes or tunnels for open conduit at much increased cost.

2538. The plan which Mr. Bateman has laid before the Commission is that instead of following the windings of the valleys he should prefer to make his line as short as he could, and to make it really a series of tunnels and short open cuttings?—I do not pretend to say more upon that point than what at the moment appears to me to be correct, but this I apprehend would be the effect, the temperature of the air would be say 20 degrees, or it might be very much lower occasionally, say 15 to 25 degrees, the natural temperature of the earth in the tunnels would probably be 50 degrees, but the water would very soon cool the lining of the tunnel or the surface of the tunnel and although it would normally be at a temperature of 50 or 51 or 52 degrees, it would not remain at that, it would be cooled down by the water passing through it, it therefore does not appear to me that unless the tunnels were of very great length, the solution of this difficulty would be attained.

2539. If Mr. Bateman were to carry out his scheme on that principle it might be that that objection would be done away with if the tunnels were sufficiently long and sufficiently close to each other?—It might, but I should not like as an engineer to undertake the work upon the supposition that the result would be found different from that which is realized in practice. Take such a year which I well remember as 1814. I was very young then, but I have a perfect remembrance of it. In that year the frost lasted 13 weeks, in the winter of 1813-14 the Thames was frozen over: not frozen over as we have sometimes seen it of late years, but frozen over quite solid, and fairs were held upon it.

2540. Assuming the surface to be frozen over in one night's hard frost, in such a conduit the snow would no longer of course have any effect?—The freezing over would be rather beneficial than otherwise, but the friction would be greatly increased by the sheet of ice formed on the surface.

2541. That would be a case which you would not dread except in the case of the breaking up of the ice?—When the ice does break up, of course it is a very serious thing, but if it were frozen over, and the snow only came after it, the tendency of the snow would be to operate like a blanket—it would keep it to a certain extent warm, at least as warm as the snow, which would possibly be nearly 32 degrees.

2542. Mr. Bateman calculates that there would always be a fortnight's supply in his reservoirs near London, to be conveyed thence by pipe. Do you think that that would be an insufficient period to meet the emergency of such a case of frost?—Yes. I should think it would. My view is governed by the enormous length of this plan. I understand that it is to be 170 or 180 miles, and it might even turn out to be more on an accurate survey, because of course it would be a very important thing to overcome engineering difficulties by winding round the country if you could overcome them in that way, and that in all probability would add something to the length of the line.

2543. Do you think that that is a difficulty which in your view is insurmountable?—I do not know any mode of overcoming it in such a plan as this to which I have alluded. I should think it is a serious difficulty. What has been suggested, viz., keeping the existing London establishments up, of course would overcome it.

2544. You have also taken exception in answer to Sir Benjamin Phillips to the possibility of their being a disturbance in the country, during which, the pipes being destroyed—you are quite well acquainted with the Paris waterworks, are you not?—Yes.

2545. Do you know whether, when they were deciding upon bringing the water the great distance of length that they have done in Paris, that matter was one which was brought under their consideration?—I do not know at all, but I know that foreign Governments view these things very differently from what we do; they would not, in case of a war, care one straw about the supply of the inhabitants of Paris; they would let them go to the Seine or anywhere else to get water for the town; they would not care about that, but that would not answer in a city like London.

2546. Still, in the case of Paris, that has not been considered a sufficient objection to their bringing the water from a distance of considerably more than 100 miles?—I do not know whether it has been considered or not; they have actually proceeded to bring water that distance, and have completed a large portion of the work.

2547. You stated that your experience of cases in which this point has arisen extended to cases abroad where you have been consulted professionally?—Yes, for instance, Copenhagen is a remarkable case. At Copenhagen I was consulted, and there they declined to go out to a very magnificent lake of comparatively soft water, called the Fure Sæ, although it was only five English miles distant.

2548. Was that on the ground of the fear of the water supply being cut off?—Yes, and being interfered with in other ways which I have mentioned, and they were very desirous to have the water supply within reach and under the command of the guns of the fortifications, and at the present moment they have large lakes formed under the walls into which the water is brought. There are many other cases. I was concerned personally at Warsaw and various other places abroad where questions of this kind have arisen.

2549. (*Mr. Prestwich.*) In Paris they bring the water from two sources of supply by two separate aqueducts, do they not, and I believe they are going to have a third?—They do, but it is a very remarkable thing that at Paris they proceeded upon the opposite principle and went to a great distance for the purpose of getting hard colourless water; they would not have soft water, they might have obtained soft water very much nearer, but so different is the view taken by the chemists of different countries that at Paris they actually went away for the purpose of securing a harder water, containing carbonates under the idea that it was more beneficial for the health of the community than soft water.

2550. They have gone to the chalk districts I believe, 100 miles from Paris?—Yes, one of the places I think is near Sens.

2551. One is in Champagne and the other in Sens?—Yes.

2552. (*Sir B. Phillips.*) Have you ever considered any other scheme for supplementing the supply of water to London?—I have not considered any scheme since about the year 1847, when I had a scheme of my own the particulars of which I will give you and the objections to it. That scheme was to bring water from the Thames near Bray, being between Windsor and Maidenhead a very suitable situation, where the water could have been collected above any large population, (although there are Oxford and one or two other places above, they are very remote and at that distance they would do no harm to the water,) and the country was exceedingly suitable for the purpose of conveying it. The project was this: to bring the water after filtering it, along a covered tunnel to a reservoir immediately under Hampstead, and there to raise it by large Cornish engines into reservoirs and allow it to run down to the works of all the companies, and to deliver it to those companies to be afterwards distri-

buted by them. That turned out to be an exceedingly feasible plan, but then the great objection to it was not only that the companies perhaps would not have received the suggestion, or acted upon it if the work had been carried out, but also that the point at which the water was proposed to be taken was above the Royal domains at Windsor, and there certainly was a very considerable objection to taking any supply from the Thames on that account at a point above Windsor: in fact I do not know how the opposition which would arise from that cause could be met, and after we had made our plans and accomplished the scheme in an engineering sense, we were obliged to give it up, we found that the Court did not receive the suggestion with favour, and we knew that it would be absolutely impossible to carry the measure unless we could have the Court with us.

2553. The great complaint of the London water at present is not the quality of the water itself so much as the polluted district through which it passes?—That, I think, there is the greatest possible amount of misconception upon: there is a great deal of prejudice, not unnatural at all, but still amounting to prejudice, upon that question. I believe, in fact I know that the water of the Thames at Hampton is very excellent water, very pure, very free from organic matter, and that what little organic matter it does contain is of a very innoxious character. But the simplest way of dealing with the Thames, if it be desirable to do so, is, in my opinion, not to take the water higher up, but to deal with the much smaller quantity, and bring the sewage lower down. It would be infinitely better, even if the water companies did it at their own expense, to bring the sewage of Oxford and of those other towns which are of considerable size out of the valley than to take the other more expensive and more objectionable course of deriving the water of the Thames at a higher source. There is no difficulty in purifying the river; and if I may state my view, I will put it in this way, that, whereas in my friend Mr. Bateman's scheme you are dealing with 130,000 acres, the valley of the Thames contains nearly 20 times that quantity. There are 2,400,000 acres in the valley of the Thames, and therefore you are always safe of an ample supply, if proper means be taken, and I am not disinclined to say that the companies ought to do something towards it.

2554. You know very well, I daresay, what the powers given to the present Commission are?—Yes.

2555. You are therefore aware that at present we have not the power of inquiring into the question which you are about to open?—No, I am not going to open any question relating to any other point than the question of the supply of London from remote districts, and the Thames having a remote source, the water must come from a remote source, even if it comes from the Thames. The case of the Thames is only a correlative of the channel which Mr. Bateman proposes to make. If you only purify the Thames you may use a naturally made channel instead of an artificially made one; it is just the same thing in the end.

2556. (*Mr. Harrison.*) Do I understand you to say that the opposition from the Royal domains at Windsor or the Crown would, in your opinion, be sufficient to put a stop to any scheme for taking the waters of the Thames from their sources?—I do not say so now, but at that time it was certainly apprehended that it would be so. From intimations we had then we were led to believe it was considered very objectionable on that ground.

2557. Assuming that Mr. Bateman's plan were carried out of having a reservoir at Stanmore, or the plan of Mr. Hemans of having reservoirs, I think, near Hounslow, would there be any difficulty in having a constant high level supply from such a distance from the point of the delivery pipes in London of the existing companies?—I think not. Of course it is a question of the magnitude of the pipes, and that only. The fact, as regards the piping and the constant supply, is this, that at certain periods of the day, generally between 9 o'clock and 11, in the morning, the quantity of water that is delivered is double the average quantity for the whole twenty-four hours, and consequently the main pipes must be made large enough for that purpose. Where the supply is given on the intermittent system the companies spread the delivery just as they think fit over a great number of hours, as much in one hour as in another, but on the system of constant supply they lose the command of the delivery entirely.

2558. (*Sir J. Thwaites.*) What is your opinion with regard to the constant supply as compared with the intermittent system which is now in operation?—The constant supply is much more beneficial than the intermittent supply *per se*, the difficulty is in changing from the one to the other.

2559. Is that difficulty in the mechanical arrangement in the pipes and taps and so on?—Chiefly so. Of course you must have a different organization from what you have now—in point of fact there is scarcely any organization—and people must submit to the inspection of their premises from time to time, but that need not be unpleasant nor need it be frequent.

2560. Under proper inspection, assuming always that the pipes are equal to the pressure and the taps properly formed for the constant supply, do you think that the health of the public would be promoted by having their supply of water constant instead of holding it in vessels that are unsuited to the purpose?—As regards the poor I have no doubt that it would be so, as regards the middle and upper classes I do not think there is anything in that point, because we all have in our own houses admirable receptacles for water, it is quite immaterial to us.

2561. Even under proper regulations is it not your opinion that there would be a waste of water with the constant as compared with the intermittent system?—No, that I can give the fullest answer to. On the contrary where the constant supply is well managed the waste of water is less than upon the intermittent system. I can give you a very remarkable instance, one among a considerable number, but it is so remarkable in itself that it is worth mentioning to you. A few years ago the City of Norwich Waterworks were transferred from a very old-fashioned company to a new one, by whom the system of constant supply had been accepted under an Act of Parliament, that is to say: it was imposed upon them. They tried to work it upon the old principle, and the consequence was that in a very short time the delivery amounted to 40 gallons per head per diem, and that amount of consumption exhausted all their pumping power. They could do no more and the consequence was that they were obliged to shut off the water at night, and the company fell into a state of ruin; all their efforts were insufficient to check the waste, and the work was very nearly being closed. I was called in amongst other persons, and they obtained a very good manager, and under my advice they applied for an additional Act of Parliament to enable them to correct the fittings. With some difficulty—for the bill was opposed as is almost always the case, for there is great jealousy about internal inspection, and so on—the bill was carried and it was put into operation, and now and for many years past, although the constant supply has been unfailingly in use, the water is never shut off, and the consumption has descended to 15 gallons per head per diem as compared with 40 previously.

2562. (*Sir J. Thwaites.*) Are you acquainted with the Hull Waterworks?—Yes.

2563. The evidence of the engineer of those works was to the effect that the substitution of the constant supply for the intermittent system had produced a saving of 25 per cent., have you any remark to make upon that?—I do not know what to say about the Hull system. I think that is exceedingly likely, but the Hull system is a very peculiar and exceptional one; there they pump into a standpipe without the aid of reservoirs, and it was very difficult for them to maintain a good supply. I believe they found at Hull that a considerable saving was effected, but I cannot give the amount.

2564. (*Mr. Harrison*). In your large experience of

T. Hawksley, Esq.

27 March 1867.

these matters have you found that where waterworks have been taken out of the hands of private companies and placed in the hands of public bodies, they have generally been used for the advantage of the town more largely than while they were in the hands of private parties?—No, I have not found it so. In general the management by public bodies is more defective than the management by companies, and for obvious reasons. The public bodies in general are more under external influences and are not capable as a rule (there are a few exceptions) of checking waste and the general experience is that the water, is delivered nominally in larger volume but not by any means more effectively by public bodies than by companies.

2565. My question applied more to corporate bodies undertaking works with a more comprehensive system in view than an individual company would have?—No, I think it would not be so, my experience is that with regard to companies the public care nothing about expenditure, and that they are always urging companies to greater and greater expenditure, whilst with regard to public bodies the public are tenacious on the subject of expenditure, and they are always making outcries against extension, and the general experience which I have had is quite to the opposite effect, namely, that companies can be urged to do greater things for the public than municipal bodies, and it is so from that moral cause; it is not because they have any greater difficulties, except those which are produced by external influences.

2566. Take the case of a city of the magnitude of London; any scheme of this sort, if it were desirable, could not be carried out by separate companies I presume?—No, they could not carry out such a scheme, that would be quite impracticable; what they would have to do would be to amalgamate. There are projects of that kind on foot now, I understand, for amalgamating, the gas companies, as has been done in Paris. There is no difficulty in amalgamating, except, of course, that which arises from the settlement of conflicting interests.

2567. There have been many calculations made and published reducing the value of soft water to *£ s. d.*; in your experience you probably have analyzed several of those statements?—Yes, often.

2568. Would you give the Commission the result of your experience upon that?—The result of my experience is this (I am not going to depreciate the value of soft water, because I do not think it is the monetary value alone which is to be taken into account), that there has been the greatest exaggeration upon these subjects. I know a case, for instance, in Lancashire, where an estimate was made of that kind as to the saving of soap, and it turned out upon a critical examination of all the circumstances, that the soap to be saved was double the quantity that had been used. The quantity of water that is used for detergent purposes, except where there are manufactories, is very small indeed, and now since the duty has been taken off soap the question is one of much less importance than it formerly was, and with regard to extractive matters, such as teas and beers and so on, all chalk waters operate just as well as the other waters, inasmuch as they become quite soft in boiling.

2569. Have you looked at the scheme of Mr. Hemans?—Only generally; I can say no more upon that than I have said upon the other. I have only looked at it generally, I know the country.

2570. Your attention has been given, has it not, for several years past, more or less to the question of supplying Liverpool with water from the Bala Lake?—Yes, I had a very great deal to do with that and with the projected supply of Liverpool from a great many other places as well.

2571. In your investigations into the question of taking water from the Bala Lake were there any special circumstances which occurred to you as likely to lead to a strong opposition either from the riparian proprietors or fisheries, or matters of that sort?—I believe that it is quite impossible to obtain the water of Bala Lake; it was all but impossible at that time (1846) if indeed it could be at that time called a Bala Lake scheme at all, for in point of fact it was a River Dee scheme; the water was to be taken about two miles above Llangollen, at a place called Llantisilio, 20 miles from Bala, and instead of being Bala water, the Bala water was only a comparatively small portion of the stream, the river Treweryn, and a great many other rivers came in between; but the first objection to the Bala scheme was the extreme brownness of the water; the Dee is about the brownest coloured stream which I know anywhere.

2572. But the water is not brown in Bala Lake itself?—Bala Lake is very brown, but not so brown as the Dee, and the Treweryn is browner than Bala Lake. But the great difficulties are these. In the first place an immense system of canals is dependent upon that lake for its supply of water. The canals take 20,000,000 gallons a day, and they are unable to part with any of it as the quantity is insufficient for them. In the next place there are the rights of Sir William Watkins Wynne, which he is totally unwilling to part with, and which he possesses under an Act of Parliament acquired since the period I am speaking of, for he was so jealous upon the subject after that endeavour to take the water to Liverpool that he obtained an Act of Parliament himself; those rights are so extensive and he is so powerful that it is not at all likely that anything could be done there without his full consent. Then the next thing is that in consequence of the development of the coal-field down the course of the river Dee, many works have been established and the riparian owners, and especially those who have works upon the river, are very much opposed to the abstraction of the water. Then, again, we come down to Chester, and find the corporation of Chester are exceedingly averse to the abstraction of the water, and then we come to the scour of the estuary, and there the utmost opposition may be expected. I have no doubt that it will be utterly impossible for Liverpool to acquire a supply of water from Bala Lake. But supposing it were worth their while to resort to a more distant source, Windermere is quite open to them, because Windermere is on the margin of the sea, within a very few miles, and there the quantity of water is superabundant, and the rights in the water issuing from the lake are very small indeed.

2573. At Windermere the level is so low that it would require pumping, would it not, when the water was brought to Liverpool?—Yes, but then pumping is not a heavy thing. When I mention that in general the cost of the pumping does not exceed a farthing per 100 feet of lift for every 1,000 gallons, it is not a very large part of the expense. The fact is that pumping schemes cost, as a rule, about one-third of gravitation schemes. Pumping schemes are very much cheaper indeed, even when you capitalize all the cost of coal and labour, and take into account the machinery which is used, every case must however be judged of by itself.

2574. (*Col. Harness.*) Does that farthing include a return upon the capital?—No.

2575. (*Mr. Prestwich.*) It depends upon the length of the aqueduct, does it not?—No, excepting as a question of friction; the friction adds to the head, but except as to that it does not enter into the calculation of the cost of pumping.

2576. (*Col. Harness.*) It includes all the current expenses?—It includes everything connected with the elevation of the water, all the current expenses.

2577. But no return upon the capital?—No.

2578. (*Mr. Prestwich.*) You stated that it was cheaper to supply water by pumping than to bring it by gravitation; but that would depend, would it not, upon the distance which it is brought by gravitation?—Yes. In all cases in which you have to impound water it is the impounding of the water which occasions the enormous cost of the gravitation works.

2579. What would you say in such a case as the New River?—But the New River Company does not impound, except in so far as the reservoir which I

have mentioned is concerned. The New River Company takes the water from the Lee through a measuring instrument, and then passes it down the channel to London without impounding it.

2580. (*Mr. Harrison.*) Just to follow up that question about the Vale of Llangollen, applying your experience in that case to Mr. Bateman's plan on the one hand, or Mr. Heman's on the other, should you anticipate an equal amount of objection to be raised to any scheme which proposed to take water from the Welsh mountains or from the Cumberland lakes?—No, I think not in the same proportion. The rights on the river Dee are very special, and I think the influences which would be brought to bear are more powerful upon the Dee than they would be upon the Severn, considerable as they are upon the Severn.

2581. Taking the Severn, perhaps the number of mills upon it is much less in proportion than the ordinary cases of compensation which are met with in the Midland Counties?—I think the mills are not very numerous, and I think the value of the mills is not very great. It is not an active manufacturing district, and the consequence is that in those districts the mills are generally employed for purposes which are dependent rather upon agriculture than anything else, for instance, in corn grinding and similar operations, those mills are not very important.

2582. With regard to supplying water to London, can you state what is now about the highest level above Ordnance datum to which it will be necessary to carry water for supplying the houses in London?—About 450 feet I should think. I am speaking now as a matter of memory, that is about the maximum, and that would apply to Hampstead.

2583. Omitting Hampstead and Highgate, and a few other places of that description, what height should you say would be sufficient?—I can best put it in this way—the height of the Regent's canal is under 100 feet above Ordnance datum; I will separate the town by the Regent's canal, which is a very good limit indeed, the height of the lofty houses above the Regent's canal—and there are very lofty houses built now—I suppose would be 80 or 90 feet, and if we put it at only 80, that would be 180 feet. Then you have the head that is required to overcome the friction of the pipes. The friction of the leading main is generally about 4 or 5 and in some cases as much as 10 feet per mile, but the friction of the distributory pipe is generally between 16 and 20 feet per mile, and you must add that, supposing you take 50 feet, for the two, it would be 230 feet, and then there would be about 20 feet more for delivery into the cistern, which would make it about 250 feet, so that you may say that for London below the Regent's canal, you would want a head of about 250 feet, and for all above that level you would want a more considerable head.

2584. I think that in that you agree as nearly as possible with Mr. Bateman's view, as to the 250 feet head?—I was not aware that he had given that.

2585. Of course there are places like Hampstead and Highgate to be supplied by pumping?—You must either have more than one system, or you must have a very elevated reservoir to supply the other district.

2586. (*Mr. Prestwich.*) A large proportion of the south side of the town could, I presume, be supplied by a reservoir at a much lower elevation?—The whole of the south side, excepting the neighbourhood of Norwood, Brixton, the Crystal Palace, and similar places could; but the difficulty in all those cases is in having so many different systems.

2587. (*Mr. Harrison.*) Do you know what the height at Norwood would be?—I should think the summit there must be 300 feet. I should not like to pledge myself to any figure, but I should think it is 300 feet above Ordnance datum.

2588. I think it is more than that, say 320 feet, and you would have the height of the house to add to that?—Yes, but I apprehend that all those peaks, which, perhaps, would not have more than 30,000 or 40,000 people upon them, and in their immediate neighbourhood, would at all times be supplied by a steam engine, because it would be very unwise to encounter the enormous cost of providing gravitation for the whole of this large district, in order to accommodate those few by that means.

2589. (*Sir J. Thwaites*) They would require to have a local lift?—Yes, that would accomplish the object in a much cheaper way.

2590. (*Mr. Harrison.*) Taking it into account that the Commissioners are anxious to investigate everything that may be said for this scheme, and also to have before them any salient objection that occurs to your mind, can you suggest anything beyond what you have stated as a really strong point of objection to the scheme of Mr. Bateman?—No, I do not come here to object, nor do I wish to object. I wish to state my independent views upon any subject upon which I may be questioned. Mr. Bateman's scheme is only put before me, I suppose, as an idea for the moment, and I am asked to direct my attention rather to the principle of supplying London from a great distance, than to discuss any scheme in particular; this is only as a mode of doing it.

2591. I am asking you your opinion upon the principle which is involved in any scheme that would have to bring water from so great a distance, whether there is any other objection which occurs to your mind beyond those which you have stated?—There seems to me to be some mistake upon the question of population, and rather a considerable mistake upon the subject of the drainage areas also. How that happens I do not know, but I have had occasion, not connected at all with this matter, to attain an exact knowledge of the amounts of the populations on the watersheds of the Thames, and the Severn, and also of the exact amount of the acreages from which the waters flow. If it be, as I apprehend it is, of some importance to know what those are, I can give the Commission the whole of them. If it be a question of supplying London from a high point on the Thames, it would be useful of course for that purpose. I can give both the rural population and the urban population, with all the particulars of their distribution, both on the Severn and on the Thames. The drainage area of the Severn down to the weir at Tewkesbury, which is the important point, that to which the tide ascends is exactly 2,680 square miles; the exact population in that area is 558,255, and the number of the population per square mile is 208. The valley of the Thames contains 3,656 square miles down to the waterworks above Thames Ditton where the supply is taken; the entire population is 861,302, and the number of persons per square mile is 235; it is a very thinly populated district indeed, in fact there are no minerals in the valley of the Thames, and that is one of the reasons why the Thames water is so valuable, and the population so scanty.

2592. (*Col. Harness.*) If you make the comparison still higher up the Thames, it will be still more in favour of the Thames?—I do not know that comparatively it will be more in favour of the Thames; that I cannot say; but it would be more in favour of Thames water. When I say comparatively, I mean as between the Thames and the Severn.

2593. The population would get more sparse as you ascended the Thames, would it not, than it would as you ascended the Severn?—No, I think not.

2594. (*Sir J. Thwaites.*) Have you any tables with respect to the populations and acreages in a form which you can hand in to the Commission?—Yes.

The witness delivered in the following tables:

T. Hawksley, Esq.

27 March 1867.

TABLE I.—RIVER SEVERN. POPULATION on WATERSHED above TEWKESBURY.

Name of Parish or Place.	County.	Population.
Adbaston	Stafford	593
Albrighton	Salop	1,156
Acton Burnell	„	361
Atcham	„	406
Aberhafesp	Montgomery	486
Abdon	Salop	170
Acton Round	„	173
Acton Scott	„	207
Aston Botterell	„	171
„ Eyre	„	85
Astley Abbotts	„	668
Alveley	„	882
Aston	Herefordshire	34
Ashford Carbonel	Salop	282
„ Bowdler	„	106
Abberley	Worcester	692
Areley Kings	„	564
Astley	„	864
Alfrick	„	474
Alberbury	Salop and Montgomery.	1,918
Broughton	Salop	223
Baschurch	„	1,321
Berriew	Montgomery	2,155
Battlefield	Salop	81
Berrington	„	772
Buildwas	„	276
Benthall	„	499
Broseley	„	4,724
Beckbury	„	297
Boningale	„	187
Blymhill	Stafford	591
Bettws Cedwen	Montgomery	730
Bishops Castle	Salop	2,083
Burwarton	„	156
Barrow	„	365
Bridgnorth	„	5,727
Badger	„	178
Bettws-y-Crwyn	„	520
Bedstone	„	164
Bucknell	„	790
Brampton Bryan	„	450
Burrington	Hereford	231
Bromfield	Salop	621
Brimfield	Hereford	665
Burford	Salop	1,121
Bitterley	„	972
Bayton	Worcester	417
Bewdley	„	2,905
Broom	„	118
Belbroughton	„	1,995
Bromsgrove	„	10,822
Brockhampton	Hereford	140
Broadwas	Worcester	311
Bransford Chapel	„	270
Birts Morton	„	289
Berrow	„	453
Bushley	„	282
Buttington	Montgomery	925
Cheswardine	Salop	1,159
Childs Ercall	„	470
Chetwynd	„	719
Castle Caereinion	Montgomery	682
Church Pulverbatch	Salop	524
Condover	„	1,871
Cound, Cressage	„	908
Codsall	Stafford	1,204
Carno	Montgomery	969
Chirbury	„	1,538
Church Stoke	Montgomery and Salop.	1,545
Church Stretton	Salop	1,695
Cardington	„	768
Culmington	„	517
Church Preen	„	97
Clee St. Margaret	„	281
Cold Weston	„	36
Cleobury North	„	168
Chetton	„	490
Chelmarsh	„	564
Claverley	„	1,667
Clun	„	2,338
Clunbury	„	1,029
Clungunford	Salop	647
Croft	Hereford	155
Cainham	Salop	755
Corely	„	515
Cleobury Mortimer	„	1,619
Churchill	Worcester	181
Chaddesley Corbet	„	1,457
Clent	„	966
Collington	Hereford	150
Clifton-on-Teme	Worcester	542
Cradley	Hereford	1,830
Cotheridge	Worcester	233
Claines	„	8,106
Colwall	Hereford	1,628
Castle Morton	Worcester	818
Cradley	„	4,075
Donington	Salop	456
Diddlebury	„	829
Ditton Priors	„	613
Deuxhill	„	43
Dudley (part of)	Worcester and Stafford	say 15,000
Downton	Hereford	184
Dowles	Salop	98
Doverdale	Worcester	43
Dodderhill	„	1,750
Droitwich	„	2,569
Doddenham	„	278
Ellesmere	Salop	6,453
Edgmond	„	2,598
Eaton Constantine	„	242
Eyton on Wild Moors	„	451
Edgton	„	186
Eaton	„	544
Easthope	„	109
Enville	Stafford	850
Elton	Hereford	108
Eye	„	733
Eastham	Worcester	347
Elme Lovett	„	353
Elmbridge	„	391
Earls Croome	„	189
Forton	Stafford	729
Forden	Montgomery	926
Fitz	Salop	323
Frodesley	„	256
Grinshill	„	317
Great Ness	„	573
Great Bolas [Bolas Magna]	„	278
Garthbeibio	Montgomery	326
Guilsfield	„	2,634
Great Dawley [Dawley Magna]	Salop	11,013
„ Witley	Worcester	445
„ Malvern	„	6,245
Grimley	„	776
Glazeley	Salop	67
Greet	„	129
Hirnant	Montgomery	295
Hordley	Salop	291
Halston	„	33
Hadnall	„	456
Hodnett	„	1,714
High Offley	Stafford	883
Hinstock	Salop	791
Habberley	„	112
Harley	„	220
Hyssington	Montgomery and Salop	341
Hopesay	Salop	676
Hope Bowdler	„	178
Hughley	„	98
Highley	„	407
Himley	Stafford	367
Halesowen (Part of)	Worcester	6,643
Heyhop	Radnor	283
Hopton Castle	Salop	138
Hope Baggot	„	82
Hopton Cangeford	„	30
„ Wafers	„	440
Hanley William	Worcester	120
Hanley Child	„	199
Hartlebury	„	2,115
Hampton Lovett	„	185
Hagley	„	963

Name of Parish or Place.	County.	Population.
Hallow	Worcester	1,507
Holt	„	295
Hadsor	„	158
Hinlip	„	136
Hanley Castle	„	1,733
Hanwood	Salop	288
Halford	„	141
Holdgate	„	196
Ightfield	„	344
Knockin	„	289
Kinnerley	„	1,310
Kenley	„	235
Kinnersley	„	208
Kemberton	„	244
Kerry	Montgomery	2,075
Kinfare	Stafford	3,551
Kyre-wyard	Worcester	152
Knighton	„	570
Kinlet	Salop	424
Kidderminster	Worcester	17,912
Knightwick	„	166
Kingswinford	Stafford	34,257
Kempsey	Worcester	1,433
Knighton	Radnor	1,853
Llangynog	Montgomery	601
Llanwddyn	„	529
Llanymynech	Salop	951
Llandysilio	Montgomery	689
Llanyblodwell	Salop	1,008
Llansaintffraid	Montgomery	1,255
Llansilin	Salop	2,002
Llanfechan	Montgomery	649
Llangedwyn	Denbigh	297
Llangadwaladr	„	526
Llanfillin	Montgomery	1,880
Llarhaiadr Mochnant	Denbigh and Montgomery.	2,304
Llanarmonmynydd mawr	Denbigh	140
Loppington	Salop	575
Little Ness	„	238
Llanfihangel	Montgomery	950
Llangadfan	„	1,028
Llanerfyl	„	885
Llanllugan	„	304
Llanwyddelan	„	476
Llanfair	„	2,584
Llangynyiew	„	602
Llandrinio	„	910
Longnor	Salop	244
Longdon	„	88
Leighton	„	340
Longford	„	214
Llanidloes	Montgomery	3,987
Llanwnog	„	1,631
Llandinam	„	1,574
Llanllwchaiarn	„	2,394
Llanmerewig	„	148
Llandyssil	„	790
Lydham	Salop	205
Lydbury, North	„	1,025
Leebotwood	„	210
Loughton	„	100
Llanfihangel-y-Beguildy	Radnor	1,203
Llanvair Waterdine	Salop	611
Leintwardine	Hereford	1,812
Leinthall Starkes	„	144
Ludlow	Salop	5,178
Ludford	Salop and Hereford.	319
Little Hereford	Hereford	458
Lower Mitton	Worcester	2,958
Little Witley	„	208
Lower Sapey	„	218
Lulsley	„	149
Leigh	„	3,060
Little Malvern	„	104
Longdon	„	626
Lee Brockhurst	Salop	133
Lye	Worcester	5,255
Lindridge	„	687
Madeley	Stafford	1,940
Moreton Corbett	Salop	255
Middle	„	802
Mucclestone	Stafford	1,610
Market Drayton	Salop	5,242
Moreton Say	„	679
Manafon	Montgomery	701
Meifod	„	1,806
Melverley	Salop	214
Montford	„	468
Meole Brace	Salop	1,215
Moughtre	Montgomery	526
Montgomery	„	1,276
Mainstone	Salop	365
More	„	227
Mindtown	„	48
Munslow	„	712
Monkhopton	„	175
Much Wenlock	„	2,494
Morvill	„	422
Middleton Scriven	„	111
„ -on-the-Hill	Hereford	445
Milson	Salop	157
Mamble	Worcester	307
Mathon	„	1,014
Martley	„	1,298
Madresfield	„	271
Martin Hussingtree	„	170
Norton	Salop	309
Norbury	Stafford	364
Newport	Salop	3,051
Newtown	Montgomery	3,692
Norbury	Salop	412
Neenton	„	110
Netherton	Worcester	91
Neen Savage	Salop	452
„ Sollars	„	189
Norton	Worcester	661
Oswestry	Salop	9,357
Oldbury	„	207
Oldswinford	Worcester and Stafford.	8,920
Onibury	Salop	375
Orleton	Hereford	600
Orleton	Worcester	99
Ombersley	„	2,463
Pendock	„	329
Powick	„	2,222
Pennant	Montgomery	712
Prees	Salop	3,097
Petton	„	45
Preston Gubbols	„	478
Pontesbury	„	3,466
Preston	„	228
Patshull	Stafford	194
Pattingham	Salop and Stafford.	1,126
Pedmore	Worcester	297
Pensax	„	503
Pitchford	Salop	180
Quatford	„	228
Quatt	„	485
Ruyton	„	1,200
Rodington	„	481
Ryton	„	213
Ratlinhope	„	285
Rushbury	„	576
Richard's Castle	Salop and Hereford.	710
Rochford	Worcester	315
Rock	„	1,379
Ribbesford	„	253
Rushock	„	159
Ripple	„	1,045
Severnstoke	„	679
Salwarpe	„	442
Suckley	„	584
Stokebliss	Worcester and Hereford.	298
Shawbury	Salop	1,027
Shrawardine	„	161
Stapleton	„	281
Shrewsbury	„	25,188
Shineton	„	175
Stirchley	„	310
Sutton Maddock	„	420
Shiffnal	„	5,923
Sheriff Hales	Stafford	816
Snead	Montgomery	59
Shelve	Salop	78
Sibdon	„	69
Stokesay	„	559

T. Hawksley, Esq.

27 March 1867.

Name of Parish or Place.	County.	Population.
Smethcott	Salop	318
Shipston	,,	186
Stanton Long	,,	234
Stoke St. Milborough	,,	573
Stottesden	,,	1,214
Stockton	,,	490
Stourbridge	Worcester	8,783
Stanton Lacey	Salop	1,598
Silvington	,,	47
Stanford	Worcester	201
Stone	,,	475
Shelsley Walsh	,,	57
Shelsley Beauchamp	,,	556
Tedstone Delamere	Hereford	205
Tilstock	Salop	656
Tong	,,	532
Trefeglwys	Montgomery	1,701
Tregynon	,,	703
Tettenhall	Stafford	3,716
Trysull	,,	610
Tenbury	Worcester	1,947
Tugford	Salop	119
Upton-on-Severn	Worcester	2,676
,, Warren	,,	338
Uffington	Salop	180
Upton Magna	,,	152
Uppington	,,	95
Upton Cressett	,,	72
Upper Sapey	Hereford	357
,, Arley	Stafford	886
,, Penn	,,	1,459
Whittington	Salop	1,895
Welshhampton	,,	516
Weston	,,	265
Wem	,,	3,802
Waters Upton	,,	206
Welshpool	Montgomery	4,844
Worthin	Salop	3,723
Westbury	,,	2,545
Wroxeter	,,	616
Withington	,,	232
Wrockwardine	,,	4,365
Wellington	,,	12,998
Weston-under-Lizard	Stafford	275
Wentnor	Salop	664
Wistanstow	,,	1,121
Woolstaston	,,	64
Wheathill	,,	123
Willey	,,	149
Warfield	,,	1,785
Wolverhampton (Part of)	Stafford	say 25,000
Wombourne	,,	2,236
Wigmore	Hereford	499
Wolverley	Worcester	2,905
Whitbourne	Hereford	891
Wichenford	Worcester	366
Worcester	,,	34,234
Welland	,,	802
Yarpole	Hereford	630
		558,255

ADDENDA:—

Population on watershed of River Severn above Tewkesbury, 558,255.

Drainage area, 2,680 square miles, or 1,715,200 acres.

Population, 208 per square mile, or rather more than three acres to one person.

TABLE II.—POPULATION ON WATERSHED OF RIVER THAMES above the Water Supply at Thames Ditton.

Name of Parish or Place.	County.	Population.
Church Charwelton	Northampton	214
Boddington, Upper and Lower.	,,	724
Byfield	,,	901
Woodford	,,	735
Astonlewalls	,,	221
Canons Ashby	,,	220
Eydon	,,	576
Chipping Warden	,,	489
Morton Pinkeny	,,	570
Edgcott	,,	103
Culworth	,,	652
Thorpe Mandeville	,,	164
Chalcomb	,,	468
Marston	,,	535
Middleton Cheney	,,	1,250
Warkworth	,,	1,111
Farthinghoe	,,	392
New Bottle	,,	557
King's Sutton	,,	1,145
Aynho	,,	595
Croughton	,,	580
Thenford	,,	112
Priors Marston	Warwick	698
Priors Hardwick	,,	323
Wormleighton	,,	203
Farnborough	,,	401
Burton Dassett	,,	655
Avon do.	,,	280
Warmington	,,	452
Ratley	,,	476
Shotswell	,,	307
Little Compton	,,	398
The whole population of county, excepting as below	Oxford	170,944
Mixbury 381		
Finmere 338		
Newton Percell 105		
Shelwell 44		
Cottesford 269		
Fritwell 542		
Ardley 169		
Hardwick 59		
Stokelyne 625		
Hethe 442		
Fringford 401		
Goddington 85		
	3,460	
		167,484
The whole of	Berkshire	176,256
Addlestrop	Gloucester	184
Moreton-in-the-Marsh	,,	1,420
Bourton-on-the-Hill	,,	506
Sezincote	,,	81
Longborough	,,	655
Temple Guiting	,,	584
Condicote	,,	182
Broadwell	,,	398
Upper Swell	,,	65
Stow-on-the-Wold	,,	2,077
Lower Swell	,,	449
Oddington	,,	588
Guyting Lower	,,	647
Rowell	,,	50

Name of Parish or Place.	County.	Population.
Charlton Abbots	Gloucester	109
Hawling	„	171
Naunton	„	535
Upper Slaughter	„	241
Iccomb	„	164
Bledington	„	396
Lower Slaughter	„	212
Seven Hampton	„	543
Wick Rissington	„	206
Westcote	„	245
Bourton-on-the-Water	„	1,011
Whittington	„	217
Salperton	„	189
Notgrove	„	162
Aston	„	325
Little Rissington	„	290
Clapton	„	123
Turkdean	„	291
Hazleton	„	185
Shipton Oliffe	„	255
Shipton Sollars	„	80
Cubberley	„	343
Withington	„	783
Compton Abdale	„	258
Hampnett	„	156
Farmington	„	284
Sherborne	„	584
Northleach	„	1,404
Cowley	„	311
Colesbourn	„	261
Yanworth	„	123
Windrush	„	290
Barrington	„	496
Barrington Little	„	151
Stowell	„	41
Elkstone	„	320
Brimpsfield	„	392
Coln St. Dennis	„	206
Chedworth	„	954
Aldsworth	„	430
Coln Rogers	„	116
Rendcombe	„	246
Side	„	55
Winstone	„	230
Duntisborn Abbotts	„	354
North Cerney	„	692
Winson	„	181
East-leach Turville	„	506
East-leach Martin	„	216
Hatherop	„	323
Southrop	„	362
Quenington	„	426
Bibury	„	899
Barnsley	„	327
Baunton	„	122
Duntisborne, Rouse	„	127
Daglingworth	„	355
Stratton	„	596
Cirencester	„	6,336
Coates	„	417
Preston	„	217
Ampney Crusis	„	648
Ampney St. Peter	„	188
Ampney St. Mary	„	125
Poulton	„	454
Fairford	„	1,654
Lechlade	„	1,328
Kempsford	„	1,007
Maisey, or Maisey Hampton.	„	352
Down Ampney	„	429
Driffield	„	132
Harnhill	„	88
South Cerney	„	1,006
Siddington, St. Peter / Siddington, St. Mary	„	474
Rodmarton	„	401
Castle Eaton	Wiltshire	286
Cricklade	„	1,820
Marston Meysey	„	215
Latton	„	308
Ashton Keynes	„	1,070
Somerford Keynes	„	386
Poole Keynes	„	180
Kemble	„	466
Ashley	„	90
Crudwell	„	799

Name of Parish or Place.	County.	Population.
Oaksey	Wiltshire	450
Hankerton	„	393
Minty	„	812
Leigh	„	312
Hannington	„	378
Highworth	„	3,629
Stanton Fitzwarren	„	205
Blunsdon St. Andrew	„	84
Purton	„	2,087
Rodborne Cheney	„	670
Stratton St. Margarets	„	1,642
Liddiard Millicent	„	588
Liddiard Tregooze	„	795
Swindon	„	6,856
Bishopstone	„	716
Little Hinton	„	298
Wanborough	„	960
Wroughton	„	1,721
Liddington	„	440
Chisledon	„	1,206
Baydon	„	380
Aldbourn	„	1,539
Broad Hinton	„	657
Winterbourne Basset	„	249
Ogbourn, St. George's	„	534
Ogbourne, St. Andrew's	„	518
Ramsbury	„	2,533
Berwick Basset	„	171
Winterbourne Monkton	„	214
Yatesbury	„	231
Avebury	„	725
Chilton Foliatt (Part of)	„	546
Froxfield	„	530
Shalbourn (part of)	„	506
Ham	„	249
Buttermere	„	128
Little Bedwin	„	496
Great Bedwin	„	2,263
Burbage	„	1,603
Marlborough	„	3,684
Huish	„	133
Fyfield	„	200
West Overton	„	910
East Kennett	„	78
Hungerford	„	450
Daylesford	Worcester	108
Evenlode	„	276
Combe	Hampshire	225
East Woodhay	„	1,533
Ashmansworth	„	201
Cruxeaston	„	76
Highclere	„	446
Woodcott	„	80
Burghclere	„	819
Litchfield	„	102
Sidmonton	„	149
Newtown	„	276
Itchingswell	„	452
Kingsclere	„	2,774
Hannington	„	264
Wolverton	„	146
Ewhurst	„	12
Baughurst	„	563
Tadley	„	900
Pamber	„	677
Monksherborne	„	649
Wootton St. Lawrence	„	917
Basingstoke	„	4,654
Sherborne St. John	„	675
Silchester	„	480
Bramley	„	467
Basing Old	„	1,193
Sherfield on Loddon	„	693
Maple Derwell	„	223
Uptongray	„	371
Newnham	„	367
Rotherwick	„	386
Hartley Westpall	„	343
Strathfield Turgis	„	195
Strathfieldsaye	„	567
Heckfield	„	1,200
Greywell	„	298
South Warnborough	„	369
Long Sutton	„	301
Odiham	„	2,833
Winchfield	„	329
Hartley Wintney	„	1,746

T. Hawksley, Esq.

27 March 1867.

Name of Parish or Place.	County.	Population.
Holybourne	Hampshire	643
Froyle	"	766
Binsted	"	1,195
East Worldham	"	235
Chawton	"	464
West Worldham	"	89
Hartley	"	92
Selborne	"	1,110
Farnborough	"	5,529
Dogmersfield	"	251
Aldershot	"	16,720
Crondall	"	2,764
Bentley	"	721
Headley	"	1,320
Kingsley	"	441
Bramshott	"	1,367
Alton	"	3,769
Rusper	Sussex	590
Ifield	"	1,307
Crawley	"	473
Worth	"	2,988
Frimley and Ash	Surrey	4,164
Windlesham	"	2,090
Bisley	"	313
Chobham	"	2,098
Egham	"	4,864
Thorpe	"	552
Chertsey	"	6,589
Farnham	"	9,278
Frensham	"	1,750
Elstead	"	818
Thursley	"	805
Pepper Harrow	"	104
Witley	Sussex	1,555
Pirbright	"	599
Hambledon	"	557
Chiddingfold	"	1,167
Godalming	Surrey	5,778
Worplesdon	"	1,753
Horsell	"	788
Guildford	"	5,846
Stoke	"	3,797
Shalford	"	1,293
Bramley	"	1,129
Hascombe	"	396
Woking	"	3,819
Pyrford	"	381
Wisley	"	166
Byfleet	"	770
Walton on Thames	"	4,010
Ockham	"	682
East Horsley	"	228
West "	"	706
East Clandon	"	283
West "	"	329
Merrow	"	363
Albury	"	1,041
Shere	"	1,503
Wonersh	"	1,438
Abinger	"	906
Wotton	"	823
Cranley	"	1,393
Ewhurst	"	881
Ockley	"	683
Dunsfold	"	716
Thames Ditton	"	2,253
West Moulsey	"	459
East "	"	1,568
Esher	"	1,460
Cobham	"	1,998
Stoke D'Abernon	"	368
Epsom	"	4,890
Ashtead	"	729
Banstead	"	1,461
Woodmansterne	"	271
Leatherhead	"	2,079
Great Bookham	"	1,106
Little Bookham	"	219
Headley	"	322
Walton-on-the-Hill	"	475
Effingham	"	633
Mickleham	"	721
Merstham	"	846
Bletchingley	"	1,691
Nutfield	"	997
Reigate	"	9,975
Buckland	"	369
Betchworth	Surrey	1,389
Dorking	"	6,997
Leigh	"	506
Newdigate	"	608
Horley	"	1,587
Horne	"	637
Burstow	"	927
Charlwood	"	1,542
Capel	"	1,074
Puttenham	"	402
South Mimms	Middlesex	3,238
Monkenhadley	"	1,053
Pinner	"	1,849
Ruislip	"	1,365
Harefield	"	1,567
Ickenham	"	351
Uxbridge	"	3,235
Hillingdon	"	7,522
Cowley	"	371
Hayes	"	2,650
West Drayton	"	951
Harmondsworth	"	1,385
Harlington	"	1,159
Stanwell	"	1,714
Staines	"	2,749
Ashford	"	784
Laleham	"	613
Littleton	"	111
Shepperton	"	849
East Bedfont	"	1,150
Feltham	"	1,837
Hanworth	"	763
Hampton	"	5,355
Sunbury	"	2,332
Whipsnade	Bedford	195
Studham	"	882
Puttenham	Hertford	135
Tring	"	4,841
Aldbury	"	848
Wigginton	"	641
Little Gaddesden	"	386
Great "	"	1,147
North Church or Berkhampstead St. Mary	"	1,638
Berkhampstead	"	4,035
Flamstead	"	1,919
Bovingdon	"	1,155
Hemelhempstead	"	7,948
Flaunden	"	244
Redbourn	"	2,043
St. Albans, St. Michael's, St. Steven's	"	11,926
Sandridge	"	833
Abbot's Langley	"	2,400
North Mimms	"	1,095
Shenley	"	1,304
Ridge	"	437
Sarratt	"	736
Watford	"	7,418
Aldenham	"	1,769
Elstree	"	402
Bushey	"	3,159
Rickmansworth	"	4,873
Edgcot	Bucks	182
Grendon Underwood	"	451
Quainton	"	929
Ludgershall	"	536
Wotton Underwood	"	266
Waddesdon	"	1,786
Boarstall	"	255
Brill	"	1,432
Dorton	"	137
Ashendon	"	325
Winchendon Upper	"	220
Winchendon Nether	"	316
Oakley	"	420
Chilton	"	364
Chearsley	"	287
Cuddington	"	590
Worminghall	"	354
Ickford	"	416
Long Crendon	Berks	1,570
Haddenham	Bucks	1,623
Aston Sandford	"	59
Shabbington	"	371
Towersey	"	449

Name of Parish or Place.	County.	Population.
Pitchcot	Bucks	36
Whitchurch	„	884
Dunton	„	106
Stewkley	„	1,453
Cublington	„	288
Aston Abbotts	„	311
Hardwick	„	708
Wingrave	„	863
Hulcott	„	143
Fleet Marston	„	23
Quarrendon	„	58
Bierton	„	691
Aylesbury	„	6,168
Marsworth	„	549
Pitstone or Pightteshall	„	457
Nettledeu	„	124
Hartwell	„	137
Dinton	„	814
Stone	„	1,094
Aston Clinton	„	1,297
Buckland	„	732
Drayton Beauchamp	„	268
Weston Turville	„	724
Halton	„	147
Stoke Mandeville	„	477
Kingsey (part of)	„	171
Ellesborough	„	724
Wendover	„	1,932
Little Kimble	„	182
Great do.	„	408
Ilmire	„	79
Monks Risborough	„	985
Princes „	„	2,392
Little Hampden	„	68
Horsendon	„	45
Bledlow	„	1,189
Saunderton	„	428
Hampden	„	266
Radnage	„	478
Choulesbury	„	105
Hawridge	„	276
Lee	„	116
Chesham	„	5,985
Great Missenden	„	2,250
Cheshambois	„	218
Little Missenden	„	1,089
Amersham	„	3,550
Chenies	„	468
Chalfont, St. Giles	„	1,217
Chalfont, St. Peter	„	1,344
Denham	„	1,068
Fulmer	„	351
Langley Marsh	„	1,874
Horton	„	810
Wyrardisbury	„	735
Ibstone (part of)	„	153
Turville	„	437
Bradenham	„	185
West Wycombe	„	2,161
High Wycombe	„	8,373
Penn	„	1,096
Beaconsfield	„	1,662
Little Marlow	„	790
Fawley	„	272
Hambledon	„	1,464
Great Marlow	„	4,661
Wooburn	„	2,245
Hedsor	„	175
Medmenham	„	380
Hedgerley	„	153
Hitcham	„	205
Taplow	„	811
Burnham	„	2,233
Farnham Royal	„	1,044
Stoke Pogis	„	1,600
Wexham	„	196
Dorney	„	367
Eton	„	3,122
Datchett	„	982
Total		861,302

Drainage area, 3,656 square miles, or 2,349,840 acres.
Population, 235·3 per square mile, or rather less than three acres to one person.

I may observe that the way in which these tables are made out is this:—All the Ordnance sheets of the valleys are obtained, and the summit line of the draining area is traced thereon. (*The witness produced several Ordnance sheets, and explained his method to the Commission.*) Where there is any doubt, the spot to which the doubt applies is visited. Upon each one of these sheets the area is taken out, and then they are aggregated together to find what the total is.

2595. (*Col. Harness.*) Would you divide a parish into drainage areas? — Yes, I would, if it is an important and populous parish, as happens to be the case at Wolverhampton. Wolverhampton is in two watersheds, we go down and look at Wolverhampton and ascertain as nearly as possible what numbers of the population there are in each watershed. And as the Commission will see I have used the geological maps for the purpose of arriving at a conclusion as to the value of the sources for water supply, inasmuch as the quality of the water depends upon the geological stratification of the country from which it is derived. I have also a table of the populations located in towns of 2,000 inhabitants and upwards as distinguishing them from little villages, detached farmhouses, and so on.

The witness delivered in the following tables:

TABLE III.—RIVER SEVERN, POPULATION of TOWNS above 2,000 Inhabitants within the WATERSHED above TEWKESBURY.—(See Census, 1861).

Bridgenorth	6,240
Bewdley	2,905
Bromsgrove	5,262
Dudley (part of) say	15,000
Droitwich	3,124
Ellesmere	2,114
Halesowen	2,911
Ironbridge	3,095
Kidderminster	15,399
Llanidloes	3,127
Ludlow	5,178
Market Drayton	3,661
Newport	2,856
Newtown	5,916
Oswestry	5,414
Shrewsbury	22,163
Stourbridge	8,166
Shiffnal	2,046
Welshpool	7,304
Wolverhampton (p. of)	25,000
Worcester	31,227
Wellington	5,576
Total	183,684 = 68 persons per sq. mile.

Watershed 2,679 sq. miles.

TABLE IV.—RIVER THAMES, POPULATION of TOWNS above 2,000 Inhabitants within the WATERSHED above HAMPTON.—(See Census of 1861.)

Aylesbury	27,090
Abingdon	5,680
Alton	3,286
Banbury	4,059
Bicester	2,798
Berkhampstead	3,631
Basingstoke	4,654
Chipping Norton	3,137
Chesham	2,208
Cirencester	6,336
Chertsey	2,910
Great Marlow	6,496
Eton	2,840
Faringdon	2,943
Farnham	3,926
Guildford	8,020
Godalming	2,321
Hemelhempstead	2,974
Henley	3,419
Hungerford	2,031
Marlborough	3,684
Maidenhead	3,895
Newbury	6,161
Oxford	27,560
Reading	25,045
Carried forward	168,104

T. Hawksley, Esq.

27 March 1867.

Brought forward - -	168,104
St. Alban's - - -	7,675
Swindon - - -	4,167
Staines - - - -	2,584
Tring - - - -	3,130
Thame - - - -	2,917
Uxbridge - - -	3,815
Witney - - -	3,458
Wantage - - -	3,064
Wallingford - - -	2,793
Windsor - - -	9,520
Wokingham - - -	2,404
	212,631

Watershed 3465 sqr. miles = 61 persons per sq. mile.

Including river Mole - -	
Epsom - - -	4,890
Dorking - - -	4,061
Reigate - - -	9,975
	231,557

Watershed 3,656 square miles = 63 persons per sq. mile.

2596. (*Mr. Prestwich.*) With regard to the use of iron pipes in the districts with which you are acquainted in the north of England, where they have a supply of soft water, do you know of any instance in which there has been any action upon the pipes?—The oxidation from the soft water, particularly from those waters that come down from the granites, which are a little alkaline, is enormous, and nothing we know of yet will stop it—it can only be delayed. It is a very excellent thing to dip the pipes in that combination of oil and tar which was patented by Dr. Angus Smith; and there are several other methods, for instance, dipping them in thin Roman cement is very useful, but the water penetrates beneath, and the coatings which are not chemically combined with the iron, and, therefore, are only a temporary protection, become thrown off, and then the oxidation goes on of course just as if the metal had been uncoated. Where the water is soft I always allow two inches for corrosion, that is an inch all the way round, but even that is not in some cases sufficient. The oxidation goes on in a very peculiar form, it begins by forming a sort of carbuncle on the surface of the pipe consisting generally of oxide of iron and some organic matter. Then those coalesce, and by degrees you get a very thick coating.

2597. Have you found it necessary to renew pipes?—Yes, the service pipes, and, with regard to mains, it has the effect of diminishing their delivering power very considerably. But a method which is in fact due to the late Mr. Appold, has been adopted for remedying this latter evil. He contrived a machine by which, in the case of main pipes, you may put a sort of piston into the pipe and put pressure on behind it; that piston moves forward along the pipe, and carries a number of scrapers with it which pare off the oxide, that has been done with considerable success in the case of main pipes, but it is not at all applicable in the case of the distributory pipes.

2598. That would keep the channel clear, but it would not prevent the wear of the pipe?—No, the difficulty about even that is this, that the oxidation goes on, and the water is for a considerable time coloured. Now, the great object of those different processes is not so much for the purpose of preventing the oxidation, although that is a very important consideration, as it is for preventing the water becoming highly coloured with the oxide of iron.

2599. Can you state anything to the Commission with regard to the action of soft water upon lead pipes?—I do not think anything of that. In the first instance, the lead is taken into solution, and you may get by chemical means a precipitate of the oxide of lead combined with the precipitant, whatever it may be; but afterwards the lead is very rarely indeed taken into solution. There is formed an oxide on the surface of the pipe which is insoluble, and the action stops.

2600. Have you had occasion to notice the relative advantages with regard to health in towns supplied with soft water and those supplied with hard water?—There is no difference whatever. The fact is the human laboratory is quite capable of separating from the water that which it does not require, and, of passing it off by the excretory organs, and it does so in all parts of the world. I imagine there are quite as many fine-raced people living in hard water districts as there are living in soft water districts. I am well acquainted with districts of both characters, and I may say that quite four-fifths of the whole surface of the globe yields hard water—in fact, the cretaceous strata and the other lime formations occupy a large portion, from which alone hard water can be obtained. I think these extend quite to four-fifths of the earth's surface.

2601. With regard to this country certainly it is?—And so I think with regard to all the countries that I have visited, and they are not a few.

2602. In speaking of the supply to Paris, the aqueducts there are covered, are they not, throughout their whole length?—I am not quite certain of that, but I believe they are covered most of the way. I know this was proposed; whether it has been carried out, or whether the cost has prevented their being completed in that form, I do not know.

2603. Have you ever gauged the Severn at Shrewsbury on that part of its course?—Not at Shrewsbury, but I have a most minute account of the capabilities of the Severn at its lower portion where it meets the tide.

2604. But not in the upper portion before it receives its lower tributaries?—No, we know very well what the volumes of floods are almost everywhere if that be the question, but I have made no gaugings.

2605. Could you give the Commission some idea of the quantity of water that passes down the Severn above Tewkesbury?—According to my recollection at the moment, the minimum quantity is somewhere about 90,000,000 gallons a day, but that is only after extreme drought. The average quantity is about 1600,000,000 gallons per day.

2606. (*Mr. Harrison.*) Is it not a great deal more than that?—No, it goes down surprisingly. A large part of the country is devoid of springs. It comprises marls and silurian formations. It is wonderful how great a difference there is between the Thames and the Severn in that respect. Mr. Prestwich will know perfectly well what I am going to mention, namely, that a large portion of the districts from which the Severn flows, is marl of the new red sandstone formation, and another portion is silurian. These furnish very few springs, the consequence is, that the flow down the Severn is very small in the summers of dry years, whereas in the Thames the strata being open, consisting of chalks and oolites to a very large extent, the discharge in summer is very large, and hence you get in the Thames a minimum of very nearly 400,000,000 gallons per diem at Teddington Lock, whilst in the Severn you get considerably under 100,000,000. I will not pledge myself without looking at the figures to what the amount is, but the minimum at Teddington Lock is, if I recollect aright, about 360,000,000 gallons in the driest weather.

The witness withdrew.

GEORGE EEDES EACHUS, Esq., examined.

2607. (*Sir J. Thwaites.*) You are a civil engineer, I believe?—I am.

2608. Has your attention been directed to the supply of towns with water?—Not generally, but I have directed my attention to it lately since the pamphlets of Mr. Bateman and others have been published with regard to that question.

2609. Have you ever carried out any waterworks?—No, I have not. It is not to the engineering points of the question that I allude in my evidence, but rather to the general principle, that, assuming other things to be equal, each county ought first to supply the towns in it and in the adjoining counties before the water is taken to any distance.

2610. That assumes that there is sufficient water in each county for the supply of the county itself?—I have taken the acreage of the different counties and the available rainfall in those counties from the best data that I could obtain, and have thus obtained the amount of rainfall that there is in each county.

2611. Do you know anything of the Welsh district from which Mr. Bateman proposes to take his supply?—I have been in Wales and I have taken into consideration the Welsh district and the amount of rainfall available there.

2612. Have you any means of knowing the amount of rainfall which is due to that district?—Only from what is published by Mr. Symons and Mr. Beardmore and others. Additional data upon that subject are wanted in order to be able to give correct calculations. I think it is quite possible that one might make useful calculations to a considerable extent on the principle I have enunciated, knowing the nature and formation of the different counties.

2613. You come here to enlighten us and therefore you ought to have made your calculations first?—I have made them on the available data.

2614. Have you no other information than that which has been published in reference to the rainfall in the Welsh district?—No, I have not.

2615. At what do you compute the amount of rainfall from that district, taking the average?—The average which I have taken is 36 inches; I have taken the rainfall of the different counties and that is the average, and the largest I have taken is 45 inches.

2616. In your opinion is there a moral wrong in taking water from one county to supply the necessities of others?—Unless it has a superabundance.

2617. I suppose that no one would doubt that the district of Wales to which Mr. Bateman points has a superabundance?—In order to test that conclusion I have taken the population from the census of 1861 and the increase of the population during the last 50 years, then, taking periods of 25 years I have calculated the probable population of each county both in England and Wales at the end of those periods, and allowing 30 gallons per head per day I have found the amount of water required for the daily supply of each county. Next taking the acreage and available rainfall of each county I have estimated the amount each county can supply; and comparing these results with the former I have found what counties have a surplus of available rainfall.

2618. When you speak of the population have you regard to that area which Mr. Bateman is dealing with, or do you refer to the population in general throughout the principality?—To the population in general.

2619. But we are speaking now of the given area from which Mr. Bateman proposes to take his supply of water, which at present is very thinly populated?—Yes, and will be for a very large period of time, even for the next 200 years there will be comparatively speaking a thin population there.

2620. Then it is quite clear that there is more water in that district than will be required by the inhabitants?—Certainly.

2621. In addition to the supply of the inhabitants will it be sufficient for the supply of the metropolis?—More than sufficient.

2622. Do you see any objection to taking the supply from that district?—No, it is at some distance, but I think it is the nearest that there is for obtaining soft water in any large quantity

2623. It is the nearest you mean for the supply of soft water to the metropolis?—Yes, if delivered by gravitation and at the requisite height in London.

2624. You have not looked into the engineering scheme I presume?—No, I am not prepared to give any evidence on the engineering. If the Commission wish it I will place a table before them of the calculations which I have made.

2625. (*Mr. Prestwich.*) With regard to the lake district, what is your opinion of the surplus waters in that district?—I find that they will be required for some of the more populous counties, that Lancashire and some other counties will require the surplus water which they will have available. Warwickshire, Lancashire, and Durham will in the course of time be so thickly populated, (if they increase in anything like the same proportion which they have done hitherto,) as to require the surplus water that may be available from the lake district of Cumberland and Westmoreland.

2626. Have you made any estimate of the quantities of water to be supplied from those districts in Wales, and in Cumberland, and as to the needs of the population in the several districts?—Yes, I have done that, and in this way have arrived at the result shown on a map that I have made, on which I have drawn prohibitory lines, because the counties of England north of the one line would require the water that is available from the lake district; and the counties of Wales south of the other line would require their own available rainfall for their own water supply.

2627. That is merely a matter of opinion; but have you any experiments, or have you any estimates upon which you have founded your conclusions which you could lay before the Commission?—I have made a calculation, from information which I have obtained, which would apply to the different drainage areas. (*The witness delivered in a table.*)

2628. (*Sir J. Thwaites.*) In dealing with this question as a practical engineer, as I assume you to be, one would naturally suppose that your attention had been directed to the area from which it is proposed to obtain a sufficient supply of water, and not merely to have taken the population of the several counties as you have done in this table?—It was as a general principle that I went into the matter.

2629. (*Mr. Harrison.*) I gather that your view is that any scheme for taking water either from Wales or from the lake district ought not to be allowed on the ground that all those waters will be wanted in the course of 100 or 200 years for the supply of the inhabitants of the manufacturing districts in the one case, and of the counties in the other?—I do not go to the extent to say that we ought to provide for the wants of a generation 200 years hence, but that we ought to take the water from that district, allowing other things to be equal which can best spare it. I find that North and Mid Wales taking them as counties, (and whether I take them as counties or as drainage areas, the result will actually be the same, because the counties taken collectively include the drainage areas referred to in the scheme of Mr. Bateman, and in the scheme of Mr. Hemans,) I find in that way that North and Mid Wales have in all cases in every county a surplus quantity of water, and are likely to have even if I extend the calculations over a period of 200 years.

2630. On what ground do you base the statement that the waters from the drainage area mentioned by Mr. Bateman ought not to be taken away?—I say that they may be taken away, because there is a surplus, and there will be a surplus available from that district

G. E. Eachus, Esq.

27 March 1867.

which Mr. Bateman refers to, but not from South Wales. Mr. Bateman does not, I think, propose to take from South Wales.

2631. I think that part of his scheme would go over the borders into South Wales, into a part of Cardiganshire?—Although I have drawn that line along the northern boundaries of Cardigan, Brecknock, and Monmouth, I do not mean to say that it should follow exactly those boundaries.

2632. But the line which you have drawn precludes the taking of water from the district of South Wales. Mr. Bateman's area appears to be southward of that line, and you have no objection to some portion being taken south of that line, but you do object to the lakes being taken?—Just so; on account of the population of Lancashire and the other counties.

2633. (*Sir J. Thwaites.*) If I understood you rightly, your former answer was to the effect that you object to take the water from any one county for the supply of another until the inhabitants of that county are themselves supplied; but you go beyond that in your answer now, inasmuch as you say that you object to taking the supply either from the lake district or from that part of the Welsh district for London, which supply may be required for the large and densely populated districts in Yorkshire and Lancashire?—My former answer alluded to the principle on which I based my calculations, and my latter answer gives the results of those calculations.

The witness withdrew.

Adjourned to Wednesday the 10th of April at half-past 11 o'clock.

Wednesday, 10th April 1867.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND, K.G., IN THE CHAIR.

Sir JOHN THWAITES.
Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.
THOMAS ELLIOTT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

Dr. Lyon Playfair, C.B.

10 April 1867.

Dr. LYON PLAYFAIR, C.B., examined.

2634. (*Chairman.*) What position do you hold?—I am Professor of Chemistry to the University of Edinburgh.

2635. To what other societies do you belong?—I am a Fellow of the Royal Societies of London and Edinburgh, and I am now Vice-President and was formerly President of the Chemical Society of London.

2636. You have no doubt given considerable attention to the subject of water supply to towns?—I was a member of the Royal Commission for the Health of Towns, and was for a long time chemical adviser to the Board of Health in London.

2637. Therefore the quality of water has naturally come under your consideration?—Very much.

2638. Have you made any examination of the water that is supplied to Glasgow by the new waterworks?—I have not made any special analysis of the water, but I have examined the relative effects upon dyeing of Loch Katrine and the Clyde water.

2639. With regard to the water supplied to London, what course did your examination take?—I frequently analysed in former years the water supplied to London, but I have been 10 years absent from London, and have not done so recently.

2640. To what part of London were your inquiries specially directed?—To all parts of the river, high up the river and down as far as the Lambeth Waterworks, and even to London Bridge.

2641. Did you analyse any of the water after it had become the property of the various companies?—Yes, frequently.

2642. How would you describe that water generally?—At that time, 10 years ago, it was becoming impure as it approached London, it was purer higher up, but as it got nearer the metropolis it became too impure to be wholly desirable for drinking purposes.

2643. You are speaking now, are you not, of the water that was found in the river itself?—Yes, and also of the water as supplied to the public.

2644. With regard to its hardness, what should you say was its peculiarity in that respect?—That it is a hard water. It is not so hard a water as is supplied to many places, but it is decidedly hard water.

2645. Could you mention the degrees of hardness?—I can only do so from memory. It averaged from 13 to 14 degrees on Clark's scale.

2646. What is your opinion, first of all, as to the effect upon the general health of the population, and, in the second place, commercially, in the use of hard water compared with soft water?—As a sanitary question, if the water is otherwise pure, I do not think that mere hardness is of much importance as to health, but it is of the greatest importance as regards the economical use of that water, and its comfortable use for the population. The effect of a hard water upon its ordinary detergent use is seen in the waste of soap and the difficulty of washing which washerwomen experience, and they are far more important members of the industrial community than is generally supposed. In the case of a dozen of shirts, all the interests of the cotton grower, the cotton spinner, the weaver, the shopkeeper, and the sempstress, may be represented at about 72*s.*, but the washerwoman's interest in that dozen of shirts is 117*s.* In other words, the washerwoman derives her profit from the dozen shirts by washing three per week for a period of three years, so that her profit during that time is nearly double that of all the other interests combined. Therefore, anything that will promote economy in such an occupation is always of much value, for the industry of the washerwoman is in reality large, although not usually considered important on account of its great division.

2647. I gather from your statement also that the mass of the population would be likely to be more cleanly, and therefore more healthy, if the water were soft, and less soap were used, than if the water were hard, causing a great difficulty in producing lather?—Yes, it is a curious thing that one never washes one's hands in a basin with hard water; where the water is hard you take a small quantity of it in the hand itself, and rub the soap until it forms a lather in the small quantity of water that is in the hand, and you merely use the water in the basin to rinse off that which you have employed in cleansing the hands; but with soft water you use the whole mass of water for detergence, and therefore it is much more effective.

2648. And it is thereby more conducive to health?—Yes, a more thorough cleansing takes place.

2649. So that if it were a question of obtaining either hard or soft water for a population at the same price, you would give the preference largely to soft water, taking all the purposes into consideration?—At a very great difference of price I would give the preference to soft water, because the economy in manufactures is so enormously great with soft water.

2650. Could you give us any illustrations of the

economical use of soft water in manufactures?—I could give an instance to show the great difference caused by even a small per-centage of additional impurity in a water. In the river Clyde there is a dam or weir across the river to dam up the fresh water for the supply of the manufactories; below this dam several sewers come in and deteriorate the water very slightly as regards analysis, but very greatly as regards its effect upon manufactures. A piece of calico, above this dam, although the difference in value of the water is only about half a grain per gallon of impurities, requires four ounces of madder less to bring it up to the same dye; below the dam of course it requires four ounces more, and the difference of that to an ordinary work where they dye 1,000 pieces a day is 1,562*l.* in the year.

2651. Do you mean that that represents the difference between the use of the water above this dam and below?—Yes; the calico printers dyeing with the water above the dam would save 1,562*l.* a year, supposing they dyed 1,000 pieces a day, which is what good works would do, and they would have to spend that money if they used the water below the dam.

2652. Therefore, that is not a distinction between softness and hardness, but a question of purity or impurity?—In this case the deterioration of the water is owing to its containing iron; the water contains half a grain of oxide of iron below the weir more than it does above.

2653. But have you gone into the question of hard water or soft water as regards manufactures?—I have gone into that, and I have been engaged in a trial where a decision was given against defendants, because only half a grain of carbonate of lime, that is chalk, per gallon, was present in the water, and large damages were given in consequence. My own opinion was that the verdict was a mistake; that that small amount of carbonate of lime did little injury to the water for manufacturing purposes, but the opinion of my brother chemists and the opinion of the referee were different.

2654. What case was that?—That was the case of Higginbotham versus the Corporation of Liverpool, in which Mr. Grove, the Queen's counsel, finally acted as arbitrator.

2655. You say you think that hard water is not so good for manufacture as soft water?—No, I do not think it is as good for manufactures, but I think that so small a difference as half a grain of carbonate of lime per gallon is not of much consequence.

2656. Between what is called really soft water and really hard water there is a very great difference, is there not, with regard to manufactures?—Yes, a very great difference for all kinds of manufactures.

2657. (*Col. Harness.*) The question of whether half a grain of carbonate of lime, more or less, would make a difference or not would depend, would it not, upon what quantity there was in the water which contained the lesser quantity; it would be a proportional quantity?—Yes. In the case I allude to the water was tolerably pure, and this small addition was supposed to have damaged it materially.

2658. (*Mr. Harrison.*) Looking at the sanitary question again as regards general health, you appear to divide that question into the water which is used for drinking and that which is used for personal washing?—Yes. I should have explained that in extreme cases I would consider a hard water injurious to health, but in ordinary cases, such as the Thames water, I do not think it injurious to health, if there are no other impurities in the water than the mere differences in the amount of carbonate of lime.

2659. Supposing that you had a choice between a hard water such as is now supplied from the basin of the Thames, supposing it to be free from impurities of sewage and otherwise, and a pure soft water, which should you give the preference with regard to the question of drinking or its use for culinary purposes?—Undoubtedly to the soft water. In all cases I strongly recommend towns not to accept hard water. Within the last three or four weeks I have been consulted with regard to supporting a bill in Parliament for a water supply to a town, and I refused to support it because it had a water with 20 degrees of hardness.

2660. You do not consider that hardness is positively injurious to health, do you?—In some cases hard water might prove injurious, as in calculous affections and in dyspepsia, still, generally, a tolerably hard water may be taken without much inconvenience; but water of 20 degrees of hardness is very hard water, and I would much prefer even for purposes of health that it should be softer.

2661. Taking the water which comes from the springs in the chalk, do you consider that water generally to be prejudicial to health?—No, not prejudicial to health, except in the circumstances which I have mentioned.

2662. Taking the other side of the question, as to the advantages from cleanliness, both with regard to personal cleanliness and washing from the use of soft water, that you look upon as a matter of considerable importance?—Of very great importance.

2663. And you think that it is decidedly conducive to the health of a town, especially amongst the lower orders of the people?—I think it is of very great importance indeed.

2664. From your experience, have you found that in washing clothes there is much difference in the wear between clothes washed in soft water and clothes washed in hard?—There is a great difference; there is much more wear and tear of clothes washed in hard water than those washed in soft water.

2665. Therefore, in that respect there would be considerable economy in the use of soft water?—Yes.

2666. Have you been able to reduce your views to anything like a money value with respect to the difference between hard water and soft water?—I have done so, but it was many years ago, and I am afraid I could scarcely find my notes upon the subject. I made calculations with regard to Manchester once, and if I can find the notes I will supply them to the Commission.

2667. I that case, I presume, you took into account the benefit to manufactures?—Yes, and I also made an estimate at that time of the increased expenditure to the town of Manchester for ordinary washing purposes from the use of hard water as compared with soft.

2668. In the case of Glasgow have you made any calculation at all with regard to that matter?—No.

2669. Are you cognizant of any calculations that have been made upon that subject?—I am not.

2670. During the time you were on the Sanitary Commission did your reports express any decided opinion as to the difference of the value of hard and soft water?—Yes, we took that particularly into our attention.

2671. Will those views be found on reference to the reports of that Commission?—They will.

2672. (*Mr. Prestwich.*) Are you aware of any disadvantages arising to health from the use of soft water?—The only question involved is, that where it is distributed upon the intermittent system of supply, and the pipes are alternately full and empty, soft water may act upon the lead of the pipes, but if the pipes are always full, and the supply is not on the intermittent system, there is very little risk, or I may say, almost no risk from that cause.

2673. In any of the towns that are supplied with soft water, such as Glasgow, or the towns in the Midland counties supplied with water off the millstone grit, have any instances of the deleterious effects of lead come before you?—I have never seen any instances where the softness of the water produced the evil if the distribution were rightly made. I have seen individual instances of lead poisoning equally with hard water where there has been an intermittent system of supply, but the theoretical danger at all events is more common with soft water.

2674. With the constant system of supply, you consider that there would be no more risk in the use of soft than of hard water?—Precisely so.

Dr. Lyon Playfair, C.B.

10 April 1867.

2675. With regard to the effects of it upon iron pipes, are you aware what the action of soft water may be?—I do not think it would have any effect at all if the water were a pure ordinary good water.

2676. (*Sir J. Thwaites.*) When you say it would have no effect, is that because the pipes are constantly charged and so exclude the air?—Yes, so as to exclude the atmosphere.

2677. (*Mr. Prestwich.*) Soft water in many cases has a very marked action upon iron pipes; it has come before us in evidence several times that tubercular concretions have been formed in the inside of pipes through which soft water has flowed; have you any remark to make upon that circumstance?—I should have much more suspicion of the pipes than of the water, in such a case, for instance, that the pipes had bad castings, or had pieces of graphite or some other material in them to allow those tubercular concretions to form, for I do not see why soft water should act upon iron pipes.

2678. It has not been confined to one particular district or to one particular country. A very marked case was made public some years ago at Grenoble, where the plpes had become so clogged by means of the concretions that they had to be taken up after the lapse of a few years, and fresh pipes laid down?—I have never seen that effect in any district supplied with soft water. I know numerous towns that have been supplied for a great many years with soft water, and I never heard that complained of, and no cases of that kind have come under my own observation. Aberdeen is an instance familiar to the Chairman, and I do not remember to have heard of this action there.

2679. (*Sir J. Thwaites.*) Were the pipes at Aberdeen lined?—I think not. They were laid down many years ago before lining was thought of.

2680. (*Mr. Prestwich.*) It has occurred also in the neighbourhood of Cherbourg where they get water from off the granite district; but I am informed that although the effects are occasional they are not universal, and therefore I want to know whether you are aware of any reason why certain soft waters should have that property and others not?—No, I do not know the fact.

2681. Will you allow me to ask you whether in soft water the same proportion of organic matter would not be more injurious than in water of an ordinary degree of hardness, and what would be the effect of the presence of organic matter in such water?—The effect of organic matter in the water depends very much upon the character of that organic matter. If it be a mere vegetable matter, such as comes from a peaty district, even if the water originally is of a pale sherry colour, on being exposed to the air in reservoirs or in canals leading from one reservoir to another, the vegetable matter gets acted upon by the air and becomes insoluble, and is chiefly deposited, and what remains has no influence on health. But where the organic matter comes from drainage it is a most formidable ingredient in water, and is the one of all others that ought to be looked upon with apprehension when it is from the refuse of animal matter, the drainage of large towns, the drainage of any animals, and especially of human beings.

2682. No doubt a large proportion of organic matter of such a nature would be injurious, but in ordinary cases of a river, such as the Thames above London, the action of the aeration of the water would be in that case to destroy any moderate amount of organic matter, would it not?—It would gradually, but such matter becomes insoluble more slowly than the matter of which I have been speaking; and in any case the presence of it is dangerous, and as one does not know the stage to which the oxidation has gone, the presence of any such animal matter in water is always most objectionable. It is impossible to tell at what stage it is by a mere general examination; by a chemical examination you can do so, but the presence of the most highly oxidised form of organic matter when it passes into the stage of nitrate is, I think, quite sufficient to condemn the water, because you are never sure whether it has fully passed into that stage.

2683. Is it not considered that by the time the Thames water, with which London is now supplied, reach the delivery pipes all organic matter is converted into the state of nitrates and nitrites?—I think that the evidence from the cholera of last summer was quite conclusive on that point, that it was not.

2684. That was confined to one particular district, was it not?—Yes.

2685. With regard to the presence of peaty matter in very soft waters, would not the effect of the oxidation which takes place during the flow of the water from a distance be to lessen the aeration of the water, that is to say, to remove the air from the water by the absorption of the oxygen?—Certainly its effect would be to remove the oxygen from the water whilst it was converting it into this insoluble matter, but water is absorptive of air, and it would soon dissolve it again.

2686. Then the condition of aeration would depend, would it not, upon the length of the flow?—Yes.

2687. In a drinking water do you consider it desirable that it should be well aerated?—It is more pleasant and more agreeable to the taste when it is aerated.

2688. What is your opinion with regard to the presence of carbonic acid in water for drinking purposes?—The presence of carbonic acid in water generally gives a pleasantness to the taste; if you soften hard water artificially by Clark's process, and add a little soda water to it, so as to give it some carbonic acid, you find that the flat taste is taken away, and people drink it more freely.

2689. In the supply of water to a large town what should you consider the first and most important object to be attained?—The first and most important object that I would look to is the nature of the gathering grounds, to see that they were of a character which would supply water free from any human contamination, or contaminations of animal matter; the second point that I would look to would be that the water was soft and was fit for detergent and manufacturing purposes; and the next that the storage ground and the reservoirs should be away from any neighbourhood of a city, and that they should always be kept cool, and aerated in an atmosphere where they would absorb no impurities.

2690. Should you not consider the effect of the water upon health for drinking purposes to be a matter of the first consideration?—I should consider it very important, and all the conditions which I have given have referred to this.

2691. Are you aware of any experiments which have been made with regard to the advantages of the use of either hard water or soft water for drinking purposes?—I can only rely upon the experiences of large towns where they have been supplied with hard water, and the supply has been suddenly changed to soft water; of course I do not know of the reverse instances where soft water has been suddenly changed to hard, but in the former cases I never saw any deterioration of health.

2692. Do the returns of the mortality of the towns now supplied with soft water show any improvement in consequence of the use of soft water?—I might mention such towns as Liverpool, for instance, where there has been a very large improvement in the health, but the introduction of soft water was only one of many hygienic improvements which took place at the same time; therefore, the proportion which should be attributed to that is difficult to distinguish from the others.

2693. That probably would be the case in almost all instances where a new water supply has been introduced?—It is; for a new and enlarged supply of water generally arises when a population has become

awakened to the necessity of hygienic improvements generally.

2694. Are you aware that some experiments have been made in France and in England also by Mr. Simon and others with regard to the effect of soft water upon animals?—Yes, upon cattle.

2695. Are you aware of the results of those experiments?—No, I do not recollect them sufficiently to speak of them now; I know that such experiments were made.

2696. You are aware probably that in a decision recently arrived at with regard to the supply of water to Paris, preference was given to waters of a moderate degree of hardness over those of the Morvan and the Loire?—Yes.

2697. Are you aware of any cause for that preference?—I do not attach nearly so much importance to any hygienic decisions in France as I would to our larger experience in this country, for I think that we are far in advance in our knowledge of the hygiene of cities than they are in France; and I do not think that the experience in this country justifies the selection of water of any amount of hardness if you can get soft water. The only fear of danger is as to the use of lead pipes, but the experience of Glasgow, where it was very much apprehended at one time, has shown that there is no practical danger where the pipes are always filled. There has not been a single case where it has been found, as far as I have heard, that any danger has arisen from the soft Loch Katrine water flowing through the pipes.

2698. In the returns from the different towns I see the rate of mortality mentioned, but there is no means of eliciting from such documents any contrast as to the improved condition of the health between the towns supplied with soft and those supplied with hard water?—No. I think you will find in such cases it is very much according to the quantity of water supplied. If you could get returns with reference to the quantity of water supplied per head of the population in each of those towns, you would have a better index of the influence of water than the mere quality.

2699. (*Chairman.*) In 1850 you were examined, were you not, before the General Board of Health?—I do not recollect that I was.

2700. In a report, called a Report on the Supply of Water to the Metropolis, Appendix No. 3, dated 1850, I see on page 76, "Dr. Lyon Playfair examined?"—That must refer to me, but I do not recollect the circumstance.

2701. Are you able at this period of time to recollect the evidence which you gave on that occasion, I do not mean minutely but so as to state whether or not you would generally concur in what you stated at that time?—I do not recollect even the fact that I was examined then, as I have been examined so often.

2702. I see that in your examination you gave analyses of water from different localities on the Thames, and you were asked this question: "You "have probably seen other analyses by other che- "mists; is there a general correspondence in them "with regard to Thames water?" And you said "There is very little essential variation more than "arises from waters being taken at different times "and places, and I here hand in a table of these "analyses." You probably do not recollect those analyses at the present moment?—No, but if I were to look them over probably I should remember them.

2703. (*Mr. Harrison.*) What was the year to which you referred when you were on the committee of the Water Supply of London?—It was a Royal Commission for inquiring into the state of large towns and populous districts; it sat for two or three years, and it gave in its report, I think, in 1846; it was the chief Health of Towns Commission, upon which general legislation took place with regard to the health of towns.

2704. (*Chairman*). I see you are asked this question, "Have you found reasons to modify your opinions as to the domestic value of soft water?" And your answer is "I speak with the force of increased "experience when I say that I formerly greatly "underrated the advantages of soft water;" and then you go on to show the reasons that you had for preferring soft water to hard?—Yes, I am still entirely of that opinion.

2705. (*Mr. Prestwich.*) You have referred to the effect of soft water in the use of dyes; could not that question be looked at in two points of view—one with regard to the economy in the use of the dyes, and the other with regard to the effect of the dyes themselves?—Yes; it has three influences upon dyeing: first, upon the original bleaching of the cotton; secondly, in the waste of the material used in dyeing; and thirdly, in the cleansing or clearing operations after the dyeing is completed; and in all those cases a pure water is preferable to a water containing any hardening matter.

2706. Does not water of a moderate degree of hardness bring out many colours better than soft water?—I have never found it so; I have carefully experimented, and I have found that distilled water brings out the best colours, and in all the experiments that I have made I have found that hard waters do not bring them out so well; but you will get plenty of manufacturers and dyers to tell you differently, and for this reason, that a dyer gets thoroughly accustomed to the water with which he operates, and he uses his materials and his mode of operation to suit that water; and if any other water is brought to him suddenly, seeing he is guided almost entirely by experience, he will get a worse result with a better water, because he is not accustomed to use it; and it requires the experiments of a chemist to elicit those sources of error. Every brewer who has been accustomed to brew with hard water will inform you that hard water is much better, and more suitable for brewing, whereas a brewer who has been accustomed to brew with soft water will tell you that soft water is better than hard; manufacturing use is entirely a matter of experience, in which people suit themselves to the case before them.

2707. Are you acquainted with the experiments of Du Pasquier with regard to the effects upon dyes in using distilled water, river water, and spring water?—No, I am not. I may mention that I was once the chemist to large calico printing and dyeworks, and that therefore my attention has been practically directed a good deal to that question. In early life I was chemical manager to Messrs. Thompsons' calico print-works in Lancashire.

2708. (*Chairman.*) I see in the Report of 1850, Appendix 3, you are asked this question: "Have "you been called on to analyse the Thames water?" And your answer is: "I have examined the "Thames waters as high as Henley, and also that "delivered by the Chelsea and by the Lambeth "Waterworks Companies." Then you are asked: "Will you state the general characteristics of the "Thames water you have examined as to its hard- "ness?" and your answer is: "I have found the "average hardness of the Thames water from a mean "of about 40 observations to be between 13 and 14 "degrees of hardness. I never found it above 16, and "I have seen it as low as 11. It has been stated to "average 16, but I have never found so high an "average, although occasionally it may be so high. "In two or three instances I have found it as low as "11, but this was due to accidental floods." Have you any reason to doubt the correctness of that?—No; that was my impression when I answered that question, I thought it was not so high as 16 or 17. These numbers refer to Clark's degrees, and not to those of Frankland, which have been lately generally adopted.

2709. The next question is: "Have you analysed "the water of the river Colne?" And your answer is: "I have examined various streams at Watford, "and I think the Colne among them. The Thames "has some 17 or 20 tributary streams. They cannot "be soft when the main stream is hard. I examined

Dr. Lyon Playfair, C.B.

10 April 1867.

" the degrees of hardness of the water at Henley " every day for three weeks, and did not find any very " great variation. One day the water was 16 degrees, " but it generally ranged from 13 to 14." Then you are asked: " Then you think it probable that, " as other chemists state, it may reach 16?" and " your answer is: " I think that it does so only " occasionally. I would not take the average of the " Thames water as delivered in London to be more " than 13, varying from 11 to 15." Then you are asked: " It has been stated that the Thames water is " likely to be affected by the sewage, and that about " London Bridge is softer than higher up?" and your answer is: " I should think it would become so by " the mixture of sewage water. In fact analysis " shows the presence of a much larger quantity of " organic matter at London Bridge than higher up " the stream;" have you any reason to doubt that " those remarks are correct?—Those were perfectly correct observations at the time that they were given, but I have had no experience of the Thames in the last 10 years, having been resident in Edinburgh for nearly that period.

2710. (*Mr. Prestwich.*) A large quantity of the water used in London for domestic purposes is boiled before it is used and that reduces the hardness, does it not?—Yes, it reduces it considerably.

2711. (*Sir J. Thwaites.*) You state, do you not, that water of 20 degrees of hardness would be injurious to health?—I have no direct experience that it is injurious to health, but I should not employ it habitually in my family. I do not think it is a suitable water with which to supply a town.

2712. Can you fix upon a degree of hardness which in your judgment would be safe?—If I were selecting for a town and could get it, I would prefer a water of not above three or four degrees of hardness, and I would dislike waters that are higher.

2713. Take the Thames water for example. When you get a mean of 13 or 14 degrees of hardness out of 40 tests, are you of opinion that that water would be injurious to health?—I would not say that it would be injurious to health. I think it would not, but I believe it is a misfortune that a large metropolis like this is supplied with a water so hard.

2714. You think that it would be worth a considerable sacrifice to obtain water of a less degree of hardness?—I think it would, and it would cover a great outlay to obtain water of a less degree of hardness. I think it is a pity that London cannot be supplied with soft water on account of its greater effect in detergence and for industrial purposes.

2715. (*Sir J. Thwaites.*) Do you mean on the score of health?—On the score of health the mere hardness I do not think would be injurious, at least I have no evidence to show that it is injurious. I am not a medical man, and would therefore speak with diffidence on this part of the inquiry.

2716. (*Mr. Prestwich.*) Do not some medical men consider that the presence of carbonate of lime in drinking water is rather desirable than otherwise for health?—I have seen evidence given in cases of water supply not only that it was desirable for health, but that it was absolutely necessary for the formation of the bones. But that showed a lamentable want of chemical knowledge, because the lime required in food does not come from the water but from the solid articles of food taken, and I do not think that the lime in water has any influence on the processes of healthy nutrition.

2717. (*Chairman.*) What is the quality of the water in the Cumberland and Westmorland district, and in the Highlands of Scotland?—It is generally soft where it comes from mountainous districts.

2718. Is there much lime in it?—No, very little generally, but I am not very familiar with the Cumberland district.

2719. The population are generally fine grown people, are they not?—Yes. Our Highlanders are not generally supposed to be deficient in bone or muscle.

2720. (*Sir J. Thwaites.*) Have you formed any opinion as to the advantage of a constant supply as compared with the intermittent system?—I have the greatest opinion as to the advantage of a constant supply in every way. It delivers the water always cool and in good condition; it obviates the necessity for a number of cisterns in badly ventilated houses, and especially in the houses of the working classes, and so prevents a great source of the danger of epidemics which arise from the solution of the polluted atmosphere in the water.

2721. You refer to the receptacles used by the poor to hold their water?—Yes.

2722. Have you had your attention directed to the condition of that water which, in such cases, has been held in those casks or tubs which the poor use?—Yes, I have occasionally examined them, but it is not so much within the power of a chemist to test such impurities on account of the extremely small quantity of deleterious vapours which may be dissolved in the water, and yet which may prove prejudicial to health; but I have had occasion myself to observe in my laboratory that when I was working with any particularly nasty vapour the water of the cistern got to smell offensively of it, and that therefore water is very absorptive and apt to dissolve those vapours readily.

2723. For example, supposing the case of a house where water is retained in the vessels referred to, and the house is badly ventilated, and gases are generated in the sewer and discharged, would not the water absorb a large amount of that gas?—It would absorb it very readily, and in no state can it be introduced more deleteriously into the system than in a state of solution.

2724. Then a system of constant supply would of course get rid of that mischief?—Yes, you would certainly get rid of that mischief; under that system the water is kept in one or two reservoirs common to a town, and at a place free from impurities, and it is delivered in a state in which it is immediately fit for drinking.

2725. You stated in answer to a question that you had not observed any deleterious results on the water from the use of leaden pipes; does that arise from the pipes being coated after the water has been discharged through them for some time?—When lead pipes are alternately full and empty, as they are on the intermittent system, then oxidation takes place and the lead is dissolved; but when the pipes are constantly full there is very little of this oxidation. Any efficient system of filtration removes the lead in solution, for it is but loosely held.

2726. (*Mr. Harrison.*) The water is not the only point conducive to the health of a town, for if we look at Glasgow the death rate in Glasgow is perhaps nearly as high as in any town in the kingdom?—Yes.

2727. And yet they have got the purest water and the largest supply of any town in England?—Yes.

2728. Therefore, we cannot always take the mere question of death rate as an index of good or bad water?—Precisely so; we must look at the overcrowded state of the population, at the climate, and at the habits and occupations of the population also.

The witness withdrew.

GEORGE J. SYMONS, Esq. further examined.

G. J. Symons, Esq.

10 April 1867.

2729. (*Sir J. Thwaites.*) The matter was referred to you for the purpose of ascertaining some points with regard to the rainfall of the Welsh district; are you prepared to give the Commission information upon that point?—I am; I have prepared a report as nearly as possible in the same manner as I did with regard to the Cumberland district; it is not very lengthy, and perhaps I had better read it.

The same was read as follows:—

REPORT ON THE RAINFALL OF WALES, BY G. J. SYMONS, F.M.S.

In drawing up this report I have found it necessary to make it much more voluminous and comprehensive than would at first sight appear requisite, and indeed than I at first anticipated. The principal causes of this extension have been (1) the fragmentary character of the Welsh returns, (2) my earnest desire to make the report as accurate and impartial as possible.

I proceed to explain the steps by which I have arrived at the results shown on the map which I beg leave to hand in.

On examination of the existing returns I found that the longest period for which complete Welsh registers would give the yearly ratios, was nine years (1858–1866); the first step, therefore, was to determine how much those nine years differed from the average of 20 years; singularly and most fortunately, it appears that the mean of this short period does not differ 1 per cent. from the mean of 20 years. This is shown by table I.

The next step was to take out the yearly depth in those 9 years at all stations bearing on the district (whether in Wales or England) and reduce them to ratios, (tables II. and III.) finally deducing from them the mean ratio due to each year.

Then every complete year's observations made in Wales during the said nine years was taken out and the true mean deduced therefrom; table IV. These values are shown on the map (*see Appendix A, T*), by the plain figures *not underlined*. Thus far the process has been almost identical with that adopted in my report on the rainfall in the Lake district, and thus far I think the results may be implicitly relied upon.

To determine the true value indicated by the short period gauges in the absence of standards of reference in the district is a very difficult matter.

If we take the total in the three months at the old established Welsh stations, we obtain the following values:

Station.	Oct.—Dec. 1866.	True mean. Table II.	Per Cent.
	Inches.	Inches.	
Rhayder	13·69	45·13	30
Lampeter	9·86	44·02	22
Hawarden	6·48	25·41	26
Maes y dre	6·88	24·22	28

Bearing in mind the remoteness of all these stations except Rhayader, 29 per cent. seems the most probable value for the district. An important condition is not, however, fulfilled by these stations, they are dry ones, and the average fall at them was only half what it was at Mr. Bateman's six stations. In discussing the Cumberland returns, I had to take 40 per cent. for some of the more mountainous districts and 30 per cent for the less hilly portions; it was therefore necessary to ascertain if the same rule was applicable to the more hilly parts of the Welsh district. The next step then was to take out the returns of the three months at *all* Welsh stations and compute the percentages. By discussing these in various ways, I concluded that the percentage rose 1 per cent. for each four inches of rain; we have seen that with an average of nine inches in the three months the percentage may be taken at 29; if then the average is 19 inches instead of 9 inches, 31½ per cent. should be taken. On the whole, I think that 31 per cent. (1 per cent. above Rhayader) is the most probable value, and that the range of error is nearly 3 per cent. +or—.

The underlined figures on the map have been computed with the value Oct.–Dec. 1866 = 31 per cent. of true mean annual fall, as shown in the following table:

Station.	Oct.—Dec. 1866.	True mean.
	Inches.	Inches.
Valley S.W. of Llanidloes	15·00	48·39
Hills above „	24·90	80·32
Valley at Carno	12·50	40·32
Hills near Canoffice	18·33	59·13
Valley at Llanwddyn	16·33	52·68
Hills above „	24·80	80·00

The mean of these values is 60 inches, if they had been computed with the value Oct.–Dec., = 28 per cent., the mean would have been 67 inches, and if with Oct.–Dec., = 34 per cent., 55 inches, so great is the uncertainty arising from the absence of old established stations.

The accuracy of adopting 31 per cent. is incidentally established by its making Mr. Bateman's valley gauge at Llanidloes indicate the same as the gauge established there in 1864.

In determining the probable average rainfall over the whole district, careful study of the map is necessary so as to determine, as nearly as may be, the areas to which the above quoted values apply. It will be seen that the returns are naturally divisible into two portions or groups, four stations having means between 40 and 60 inches, and two (at the back of Plynlimmon and Aran Mowddy respectively) 80 inches each; of course if we took the arithmetical mean it would imply that one-third of the district had a mean rainfall of 80 inches, which I cannot conceive to be possible, especially looking to other and wetter parts of Wales. I consider that these high values apply only to one-fifth or one-sixth of the whole district; this would give the mean rainfall for the entire area as 56 or 55 inches.

In conclusion I have to report—

(1.) *That although there are places in the vicinity of Snowdon with a mean rainfall exceeding* 110 *inches, no such falls are shown to exist in other parts of Wales.*

(2.) *That the old-established gauges surrounding the district in question have a mean annual rainfall of* 47 *inches.*

(3.) *That the new short period gauges apparently indicate a mean rainfall in the district of* 55 *or* 56 *inches, but that this value is uncertain to probably four inches plus or minus.*

(4.) *Therefore (subject to the before-mentioned uncertainty) the mean fall in three successive dry years would be* 44 *or* 45 *inches, and in one year of extreme drought the fall would only be* 36 *or* 37 *inches.*

G. J. SYMONS, F.M.S.

136, Camden Road, N.W.
March 26th, 1867.

G. J. Symons, Esq.

10 April 1867.

TABLE I.—RAINFALL of 1858–1866 compared with that of 1847 to 1866.

Year.	Burford House, Tenbury.	Orleton, Tenbury.	Haughton Hall, Shiffnal.
	Total in inches.	Total in inches.	Total in inches.
1847	27·18	27·99	23·22
1848	34·10	39·02	31·62
1849	26·19	26·95	27·10
1850	21.97	24·62	21·07
1851	23·19	23·91	22·21
1852	39·67	45·43	37·58
1853	25·73	30·16	26·20
1854	19·11	20·73	17·63
1855	21·58	28·38	21·13
1856	28·55	31·43	21·88
1857	29·59	29·18	21·00
1858	23·92	27·71	23·74
1859	21·85	26·63	27·81
1860	31·55	36·89	31·23
1861	26·72	29·81	23·80
1862	31·10	34·31	25·70
1863	24·40	27·67	21·21
1864	19·30	21·79	17·23
1865	24·45	29·88	23·25
1866	27·68	34·62	29·93
Mean of 20 years - -	26·39	29·86	24·73
,, last 9 years - -	25·66	29·92	24·88
Difference - - -	−·63	+·06	+·15

TABLE II.—RAINFALL at each of Eleven STATIONS in the years 1858 to 1866.

Years.	Rhayader, Radnor.	Lampeter, Cardigan.	Hawarden, Flint.	Maesydre, Flint.	Knowbury, Salop.	Hengoed, Salop.	Haughton Hall, Salop.	Burford, Salop.	Leominster, Hereford.	Rocklands, Hereford.	Orleton, Tenbury.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1858	35·11	36·69	21·70	21·57	26·42	31·24	23·74	23·92	22·44	24·04	27·71
1859	50·72	45·82	30·50	28·02	28·63	44·22	27·81	21·85	28·64	33·53	26·63
1860	59·52	55·30	27·80	29·00	37·87	45·51	31·23	31·55	29·67	40·77	36·89
1861	40·73	43·98	21·82	17·01	27·92	30·90	23·80	26·72	25·50	31·85	29·81
1862	47·81	43·22	30·37	24·09	30·55	34·68	25·70	31·10	29·09	35·27	34·31
1863	42·72	45·38	23·06	28·98	24·11	30·32	21·21	24·40	22·15	29·32	27·67
1864	37·02	32·58	21·67	21·19	19·32	27·29	17·23	19·30	19·43	22·28	21·79
1865	41·48	42·39	21·96	21·22	26·81	38·34	23·25	24·45	27·10	32·44	29·88
1866	51·05	50·86	29·82	26·93	31·65	40·53	29·93	27·68	31·51	37·17	34·62
Mean -	45·13	44·02	25·41	24·22	28·14	35·89	24·88	25·66	26·17	31·85	29·92

TABLE III.—RATIO at each STATION of the RAINFALL in each year to the mean of the nine years—1858 to 1866, computed from Table II.

Years.	Rhayader.	Lampeter.	Hawarden.	Maesydre.*	Knowbury.	Hengoed.	Haughton Hall.	Burford.	Leominster.	Rocklands.	Orleton.	Adopted Mean.
1858	78	83	85	89	94	87	95	93	86	75	93	87
1859	112	104	120	116	102	123	112	85	110	105	89	107
1860	132	126	110	120	134	127	126	123	113	128	123	124
1861	90	100	86	70	99	86	96	104	97	100	100	94
1862	106	98	120	99	108	97	103	121	111	111	114	108
1863	95	103	91	120	86	84	85	95	85	92	92	93
1864	82	74	85	87	69	76	69	75	74	70	73	76
1865	92	96	86	88	95	107	94	96	104	102	100	96
1866	113	116	117	111	113	113	120	108	120	117	116	115
Mean -	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0

* This register does not appear so correctly kept as the others, but as its greatest disturbing effect is only 2 per cent. I have not thought it advisable to supress it.—G.J.S.

TABLE IV.—COMPUTATION of true MEAN FALL at every STATION in WALES whereat observations are complete for any year between 1858 and 1866, both inclusive.

County		ANGLESEA.				BRECKNOCK.				CARDIGAN.							CARMARTHEN.						
Station		Beaumaris Henllys.	Llandyfrydog.	Llanfairynghornwy.	Menaifron.	Crickhowell Buckland.	Crickhowell.	Hay Penymaes.	Brecknock Treberfydd	Aberystwith.	Cardigan.	Frongoch.	Gogingan.	Logylas.	Lampeter	Kilgerran.	Carmarthen.	Carmarthen Gaol.	Carmarthen Plas cwrt Hyr.	Llandissilio Rhydwen.	Llanelly.	Pembrey (Burry Port).	Langharne Llanstrephan.
Observer		Miss Hampton.	H. Webster, Esq.	I. Williams, Esq.	Rev. W. Williams.	Mrs. Holford.	Sir J. Bailey.	Capt. Brown.	R. Raikes, Esq.	T. Paul, Esq.	G. B. Osborne, Esq.	H. Thomas, Esq.	H. Thomas, Esq.	H. Thomas, Esq.	Rev. Prof. Mathews.	Rev. D. Evans.	J. Rowlands, Esq.	G. Stephens, Esq.	W. E. Gwynne, Esq.	H. S. Morgan, Esq.	E. Bagot, Esq.	D. M. Llewellyn Esq.	W. Ainslie, Esq.
Height of Gauge above	Ground	1 ft. 6 in.	2 ft.	5 ft.	4 ft. 9 in.	2 ft. 6 in.	—	1 ft	—	1 ft.	6 ft.	4 ft.	4 ft.	3 ft. 6 in.	5 ft.	1 ft. 2 in.	1 ft. 3 in.	3 ft. 6 in.	1 ft.	1 ft.	7 ft.	11 in.	5 in.
	Sea	150 ft.	92 ft.	120 ft.	17 ft.	190 ft.	—	400 ft.	—	50 ft.	18 ft.	855 ft.	290 ft.	375 ft.	420 ft.	80 ft.	70 ft.	72 ft.	90 ft.	150 ft.	20 ft.	7 ft.	35 ft.
Year.	Ratio.																						
1858	87	—	—	—	—	—	—	—	—	—	—	—	—	—	36·69	—	—	—	—	—	—	—	—
1859	107	—	—	—	—	—	—	—	—	—	—	—	—	—	45·82	—	—	—	—	—	—	—	—
1860	124	—	—	—	—	—	—	34·58	—	—	—	—	—	—	55·30	—	—	—	—	55·52	—	—	—
1861	94	—	44·45	—	—	29·36	—	30·77	—	—	—	—	—	—	43·98	—	—	—	—	54·19	—	—	—
1862	108	—	40·14	—	—	31·29	—	32·26	—	—	—	53·68	46·50	—	43·22	—	—	45·60	—	53·06	—	—	—
1863	93	—	40·83	—	—	31·12	—	26·75	—	—	—	50·51	48·85	—	46·38	—	—	—	—	49·13	—	—	—
1864	76	—	—	—	—	38·03	—	23·28	—	—	31·68	37·20	37·36	—	32·58	—	—	38·89	40·65	38·98	—	—	—
1865	96	31·67	—	—	—	—	39·75	30·99	34·14	34·81	—	43·74	40·38	—	42·39	42·96	40·57	50·47	54·35	43·33	51·80	—	—
1866	115	44·55	—	36·33	40·03	—	—	36·65	—	47·64	—	64·74	48·12	60·23	50·86	44·06	—	48·24	53·63	46·00	—	41·93	37·36
Arithmetical Mean		38·11	41·81	36·33	40·03	32·45	39·75	30·75	34·14	41·22	31·68	49·97	44·24	60·23	44·02	43·51	40·57	45·80	49·54	48·60	51·80	41·93	37·36
True Mean		35·95	42·66	31·59	34·81	34·89	41·41	30·44	35·56	38·39	44·68	50·99	45·14	52·37	44·02	41·05	53·38	48·21	51·60	48·11	53·96	36·46	32·49

(*continued*).

County		CARNARVON.																					
Station		Bangor.	Bangor Llanfairfechan.	Beddgelert Sygun.	Bethesda Bryndderwen.	Bethesda Penrhyn.	Bettws y coed.	Carnarvon Plas Brereton.	Carnarvon Cochsidia.	Llanberis Dinorwic.	Llanberis Glyn Padarn.	Llanberis Royal Victoria Hotel.	Llangybi Cefn.	Llanllyfni Cilgwyn.	Llanystumdwy Talarvor.	Port Madoc.	Port Madoc. Hendre.	Pwllheli.	Pwllheli. Bodfaen.	Sarr Aberdaron.	Clynnog.	Snowdon Hafod-y-llan.	Conway Morfa.
Observer		Rev. J. H. Purvis.	R. Luck, Esq.	Mr. T. Searell.	Captain Francis.	Captain Francis.	Rev. S. Griffith.	J. Turner, Esq.	Mr. J. Jackson.	Mr. G. Ellis.	— Cragg, Esq.	Mr. M. Williams.	Rev. St. A. Williams.	—	Dr. J. Roberts.	Captain Mathew.	F. C. Ball, Esq.	J. T. Evans Esq.	Rev. O. Williams.	Mr. W. Jones.	Rev. R. Killin.	Mr. T. Searell.	Mr. J. Roberts.
Height of Gauge above	Ground	5 ft.	8 in.	5 ft. 8 in.	1 ft.	5 ft.	1 ft. 2 in.	10 in.	1 ft. 1 in.	1 ft. 10 in.	1 ft.	1 ft.	1 ft. 1 in.	1 ft.	3 ft.	3 ft.	1 ft. 6 in.	2 ft.	—	5 ft.	1 ft.	5 ft.	1 ft.
	Sea	105 ft.	150 ft.	330 ft.	550 ft.	1000 ft.	70 ft.	25 ft.	120 ft.	850 ft.	377 ft.	370 ft.	200 ft.	500 ft.	50 ft.	10 ft.	80 ft.	12 ft.	—	340 ft.	70 ft	1,300 ft.	15 ft.
Year.	Ratio.																						
1858	87	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1859	107	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1860	124	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1861	94	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1862	108	45·52	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	49·13	—	—	—
1863	93	44·94	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	40·98	—	—	—
1864	76	36·69	31·39	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	38·36	40·81	—	—	25·81
1865	96	33·94	33·80	81·23	52·74	51·99	54·13	30·97	—	62·19	65·18	75·51	44·43	35·45	34·10	38·38	41·22	34·35	46·27	45·50	55·43	127·38	30·80
1866	115	—	43·53	113·57	70·30	58·08	73·99	42·69	42·73	73·91	74·01	89·11	51·30	33·98	40·20	51·09	—						
Arithmetical mean		40·27	36·24	97·40	61·52	55·03	64·06	36·83	42·73	67·90	69·59	82·31	47·86	34·71	37·15	44·74	41·22	34·85	42·31	44.10	55·43	127·38	28·30
True mean		43·30	37·75	91·88	58·04	51·91	60·43	34·74	37·15	64·05	65·65	77·65	45·15	32·74	35·05	42·21	42·94	30·30	39·91	40.83	48·20	110·77	24·81

TABLE IV.—*continued.*

County	DENBIGH.						FLINT.					GLAMORGAN.										
Station	Denbigh Plas Clough	Llandudno Warwick House.	Wrexham Gwersyllt Hill.	Wrexham Brymbo.	Wrexham Grove Lodge.	Chirk Brynkinalt.	Hawarden.	Holywell. Maes y dre.	Mold. Gwynsanny.	Rhyl Gas Works.	St. Asaph, Brynbella.	Cardiff.	Cardiff Free Library.	Cardiff Town Hall.	Cardiff Spring Bank.	Cardiff Ely.	Cowbridge, The Ham.	Merthyr Tydvil, Troedyrhiew.	Merthyr Tydvil, Thomas Town.	Tynant Pentyrch.	Swansea Harbour Office.	Ystalyfera.
Observer	J. Harrison, Esq.	Dr. Nicol.	W. Lassell, jun., Esq.	C. E. Darby, Esq.	C. Napier, Esq.	Mr. Hall.	Dr. Moffat.	J. Williams, Esq.	P. D. Cooke, Esq.	Mr. Evans.	P. P. Pennant, Esq.	Dr. Vachell.	W. Adams, Esq.	T. Waring, Esq.	H. Bowen, Esq.	T. G. South, Esq.	G. W. Nicholl, Esq.	E. W. Scale, Esq.	T. J. Dyke, Esq.	F. G. Evans, Esq.	J. W. James, Esq.	J. Rogers, Esq.
Height of Gauge above Ground	9 in.	6 in.	2 ft.	3 ft. 3 in.	1 ft.	9 in.	1 ft.	5 ft.	—	4 ft. 2 in.	1 ft.	8 ft.	1 ft.	1 ft. 1 in.	4 ft. 6 in.	3 ft.	1 ft. 2. in	3 ft.	—	1 ft. 1 in.	14 ft. 9 in.	1 ft.
Height of Gauge above Sea	—	99 ft.	400 ft.	550 ft.	—	—	270 ft.	400 ft.	—	20 ft.	283 ft.	40 ft.	20 ft.	20 ft.	50 ft.	15 ft.	55 ft.	500 ft.	550 ft.	100 ft.	200 ft.	368 ft.
Year. / **Ratio.**																						
1858 87	—	—	—	—	—	—	21·70	21·57	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1859 107	—	—	—	—	—	—	30·50	28·02	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1860 124	—	30·00	—	—	—	—	27·80	29·00	38·49	—	—	—	—	—	—	—	—	—	—	—	—	—
1861 94	—	31·00	—	—	—	—	21·82	17·01	30·04	—	—	—	—	—	—	53·91	—	—	—	—	—	73·21
1862 108	—	31·95	—	—	—	—	30·37	24·09	33·04	—	—	—	—	—	—	43·85	—	—	—	—	—	66·78
1863 93	—	34·12	—	28·21	—	—	25·06	28·98	33·69	—	—	—	—	—	—	44·96	—	—	—	—	—	67·07
1864 76	—	25·35	28·25	25·09	—	—	21·67	21·19	—	—	—	36·79	—	—	—	40·42	—	—	—	—	—	61·92
1865 96	29·04	28·11	—	30·33	—	36·60	21·96	21·22	—	26·66	—	27·33	—	—	—	28·99	—	39·12	—	—	24·74	44·94
1866 115	34·43	35·55	36·62	36·15	32·84	36·34	29·82	26·96	—	26·50	29·92	—	43·38	49·42	44·46	40·56	36·67	50·27	—	—	33·05	61·69
																	41·56	59·31	58·39	59·00	33·20	—
Arithmetical mean	31·73	30·58	32·43	30·02	32·84	36·47	25·41	24·22	33·81	26·58	29·92	32·06	43·38	49·42	44·46	42·96	39·12	49·57	58·39	59·00	30·33	62·60
True mean	29·93	30·27	33·78	31·60	28·56	34·41	25·41	24·22	32·20	25·07	26·00	37·72	37·65	42·98	38·66	42·53	36·91	51·64	50·77	51·31	31·59	63·88

(*continued*).

County	MERIONETH.											MONTGOMERY.		PEMBROKE.			RADNOR.	
Station	Bala.	Bala, Llanuddwfell.	Corwen Rhug.	Dolgelly.	Dolgelly, Brithdin.	Festiniog, Blaen y ddol.	Maentwrog (Caen y coed.)	Talgarth Hall, Machynlleth.	Towyn.	Trawsfynedd.	Rhiwbryfdir.	Manafon Berriew.	Llanidloes Broomcliffe.	Tenby Caldy Island.	Haverfordwest.	Pembroke Dock.	Rhayader Cefnfaes.	Presteign.
Observer	Dr. Richards.	W. Pamplin, Esq.	W. Wagstaffe, Esq.	W. Williams, Esq.	J. Hill, Esq.	C. Casson, Esq.	Rev. W. H. Treadall.	C. F. Thruston, Esq.	Dr. C. R. Williams.	Mr. Jarret.	Mr. R. Roberts.	Miss Williams.	T. F. Roberts Esq.	Mr. Fletcher.	E. P. Phidips Esq.	E. Chevalier, Esq.	Mrs. Jones.	Captain Hannam.
Height of Gauge Above ground	1 ft.	1 ft.	4 ft.	1 ft.	2 ft.	1 ft.	1 ft.	1 ft.	1 ft.	7 in.	10 ft.	1 ft. 3 in.	3 ft. 10 in.	1 ft.	1 ft.	4 ft.	2 ft.	1 ft.
Height of Gauge Above sea	544 ft.	540 ft.	500 ft.	43 ft.	500 ft.	600 ft.	15 ft.	150 ft?	18 ft.	700 ft.	1,100 ft.	—	750 ft.	165 ft.	85 ft.	30 ft.	880 ft.	550 ft.
Year. / **Ratio.**																		
1858 87	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	35·11	—
1859 107	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	50·72	—
1860 124	—	—	—	—	—	—	—	—	—	—	—	—	—	—	56·99	—	59·52	—
1861 94	—	—	—	—	—	—	—	—	—	—	—	—	—	—	51·80	44·77	40·78	—
1862 108	—	—	—	—	—	—	—	—	—	—	—	—	—	—	38·30	46·33	47·81	—
1863 93	—	—	—	—	—	—	—	—	—	—	—	—	—	—	45·13	42·37	42·72	—
1864 76	—	—	—	—	41·23	—	—	53·01	—	—	—	26·84	—	—	40·06	36·91	37·02	—
1865 96	—	42·97	36·07	52·01	57·59	57·22	48·95	43·32	35·32	48·18	74·49	—	43·33	37·16	50·77	42·64	41·48	32·55
1866 115	65·23	—	47·55	69·68	61·71	84·72	—	—	—	59·51	114·47	—	58·07	39·31	54·97	42·53	51·05	39·04
Arithmetical mean	65·23	42·97	41·81	60·84	53·51	70·97	48·95	48·16	35·32	53·85	94·48	26·84	50·70	38·24	48·29	42·59	45·13	35·80
True mean	56·72	44·76	39·44	57·39	55·74	66·95	50·99	56·00	36·79	50·80	89·13	35·32	47·83	36·08	47·81	43·91	45·13	33·77

G. J. Symons, Esq.
10 April 1867.

2730. (*Mr. Harrison.*) Are you at all aware of the circumstances under which the particular points of those rain gauges were fixed in the Cumberland district?—I fixed them myself, and I chose them as being, as near as I could make them, a fair geographical representation, that is to say, they were not picked out as wet places; I believe that it would be quite possible to pick out considerably wetter places if the attempt were systematically made with that object.

2731. In some evidence which has been given before us it was rather stated that the gauges had been moved from time to time, and some of them were placed with the view of ascertaining the greatest amount of rainfall?—That is really untrue, because they have never been moved at all; I put them down myself, and to the best of my belief they have never been touched from that time to this; the returns have all come up to me from the persons in charge of them, and who did not know whether the object was to get a larger amount of rain or a smaller amount of rain.

2732. That was stated, I believe, with regard to Dr. Miller's gauges?—One or two were moved, but only one or two. I think the gauge at Wastdale Head was moved; that was in 1845 or 1846; that certainly was moved about 200 yards or a second one was put up about 200 yards from the former one; but I am not aware of any moving or anything of that sort having been done with the view of increasing the return of the amount of rainfall.

2733. (*Col. Harness.*) Do you know whether it was an object with Dr. Miller to try to ascertain the maximum rainfall?—Yes; but he gained that as a rule not by moving the old gauges but by putting up new ones.

2734. Still some of the gauges, as appears from his records, were placed with that object?—Yes in the case of Seathwaite and the Borrowdale Valley; in fact up to this very year, one of my correspondents, a Mr. Fletcher, a relative of the late Dr. Miller, has moved a gauge from Mosedale to close to the Stye with the view of seeing whether he could get more water reported than in the case of the Stye, but he has not succeeded in doing so. In my own case I put those gauges so as to take in the whole of the district, and it will be seen that some of them do not give nearly so high an amount as other old established gauges.

2735. To what area do you suppose that the great rainfall of the Stye applies?—The Stye itself does not probably apply to more than three or four square miles, but that is not at all taken into the calculations upon which I have based the average of 77 inches in that district. The Stye gaugings I cut out of that, because the existing proposal cannot take them in; the levels are such that they cannot take in that district, and therefore of course the rainfall is also excluded. I do not know that I have any remark to add to the report; the Commissioners will see from the map which I have handed in that up in the neighbourhood of Snowden, there really is a heavy rainfall of 111 inches, but no such falls exist in other parts of Wales. [See (1), page 12].

2736. (*Sir J. Thwaites.*) Is your summit upon the high or the southern slope up beyond Bedgellert?—Bedgellert was one of the wettest places in Wales, and this is still further up the same valley. It is rather singular that in the first place the wettest part in Wales is 111 inches, that is two-thirds of the wettest in Cumberland, which is 160 at the Stye, and also the returns which we get now for this Welsh district are about two-thirds of what we got from Cumberland, and that was just a suggestion that I threw out almost at haphazard. I thought it was about that, and the result of careful inquiry is to corroborate it.

The witness withdrew.

Adjourned to Wednesday, the 8th of May, at half-past 11 o'clock.

Wednesday, 8th May 1867.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND, K.G., IN THE CHAIR.

Sir JOHN THWAITES.	Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.	THOMAS ELLIOT HARRISON, Esq.

JOSEPH PRESTWICH, Esq.

J. Simon, Esq.
8 May 1867.

JOHN SIMON, Esq., examined.

2737. (*Chairman.*) You are a Fellow of the Royal Society are you not?—I am.

2738. And late Officer of Health to the City of London?—Yes.

2739. Will you state what your present position is?—I am medical officer to the Privy Council, and surgeon to St. Thomas's Hospital.

2740. You have no doubt given great consideration, have you not, to the subject of the supply of water to the metropolis, both in point of health, of comfort, and of cleanliness?—Yes, I have.

2741. Are you of opinion that the supply of water to the city of London is now as much as it ought to be?—I have not the quantity of that supply at this moment in my recollection. I dare say that the quantity pumped into the city, divided by the number of the population, may represent a sufficient supply per head, but of this quantity a large proportion runs to waste.

2742. (*Sir J. Thwaites.*) Do you mean the night population or the day population?—The permanent population taken from the census. I suppose that the use of water by the non-resident population of clerks, merchants, and so forth, is relatively but small.

2743. (*Chairman.*) Are you of opinion that the actual population of London, speaking more especially of the poorer classes, have not a sufficient supply?—I believe that the supply to the poorer parts of the population is, practically speaking, very far from sufficient, but that this depends rather on circumstances attaching to the intermittent manner of supply, than on scantiness of the quantity which the companies have at their disposal. Probably the state of things often resembles more or less that which I described in the City of London 18 years ago, when I first reported there on the subject. I then spoke of the supply as being, for masses of the population, in a practical sense, grossly insufficient. My language was then as follows:—"Thousands of the "population have no supply of it to the houses "where they dwell. For the possession of this first "necessary of social life such persons wholly depend "on their power of attending at some fixed hour of "the day, pail in hand, beside the nearest standcock, "where, with their neighbours, they wait their turn, "sometimes not without a struggle, during the "tedious dribbling of a single small pipe. Some-"times there is a partial improvement on this plan; "a group of houses will have a butt or cistern for "the common use of some scores of inmates, who "thus are saved the necessity of waiting at a stand-"cock, but who still remain most insufficiently supplied

J. Simon, Esq.
8 May 1867.

" with water. Next in the scale of improvement we " find water-pipes laid on to the houses, but the water " is turned on only for a few hours in the week, so " that all who care to be adequately supplied with it " must be provided with very spacious receptacles. " Receptacles are sometimes provided, and, in these, " which are often of the most objectionable descrip- " tion, water is retained for the purposes of diet and " washing, during a period which varies from 24 to " 72 hours. One of the most important purposes of " a water supply seems almost wholly abandoned, " that, namely, of having a large quantity daily devoted " to cleanse and clear the house drains and sewers, " and, in many cases where a water-pipe has been " conducted from the waterbutt to the privy, the " arrangement is one which gives to the drainage " little advantage of water, while it communicates to " the water a well-marked flavour of drainage."

2744. Does that state of things exist still?—I no longer know intimately the state of the city of London. I have ceased to be the Officer of Health of the City now for the last 12 years. Improvements have taken place since 1849; indeed I know that during the following six years, while I was still in the City, great improvements took place.

2745. Do you consider the system of intermittent water supply to be a good or bad one?—A very bad one.

2746. What is the reason which induces you to consider it a bad one?—My opinions about it are substantially those which I expressed in 1849 and 1850, in the following passages of my reports then made. From report of 1849:—"I consider the system of " intermittent water supply to be radically bad, not " only because it is a system of stint in what ought to " be lavishly bestowed, but also because of the necessity " which it creates that large and extensive receptacles " should be provided, and because of the liability to " contamination incurred by water which has to be " retained often during a considerable period. In " inspecting the courts and alleys of the city, one " constantly sees butts for the reception of water, either " public, or in the open yards of the houses, or some- " times in their cellars, and these butts, dirty, mould- " dering, and coverless, receiving soot and all other " impurities from the air, absorbing stench from the " adjacent cesspool, inviting filth from insects, vermin, " sparrows, cats, and children, their contents often " augmented through a rain-water pipe by the wash- " ings of the roof, and every hour becoming fustier " and more offensive. Nothing can be less like what " water should be than the fluid obtained under such " circumstances, and one hardly knows whether " this arrangement can be considered preferable to " the precarious chance of scuffling or dawdling at a " standcock. It may be doubted, too, whether even " in a far better class of houses the tenants' water " supply can be pronounced good. The cisternage is " better, and all arrangements connected with it are " generally such as to protect it from the grosser im- " purities which defile the waterbutts of the poor, " but the long retention of water in leaden cisterns " impairs its fitness for drinking, and the quantity " which any modern cistern will contain is very " generally insufficient for the legitimate require- " ments of the house during the intervals of supply. " Everyone who is personally familiar with the " working of this system of intermittent supply can " testify to its inconvenience, and though its evils " press with immeasurably greater severity on the " poor than on the rich, yet the latter are by " no means without experience on the subject." From report of 1850:—"I may correct a fallacy " which is apt to prevail with respect to the abundance " of supply. I have no reason whatever to doubt " that a very liberal allowance of water is daily " pumped into the City, enough, or more than enough, " so far as I know, to fulfil all necessary purposes. " But those purposes are not fulfilled by it. A cer- " tain large figure is stated as representing the average " quantity daily driven through the mains of the City; " this quantity is divided by the number of residents " within your area, and the inference is drawn that " each individual inmate of the City has at his dis- " posal 25 gallons a day, or (after deduction for public " purposes and the like) 21¼ for his domestic supply. " As an arithmetical conclusion from the premises " this may be true; nothing can be less accurate " as a practical representation of the facts. An ave- " rage amount of 3,000,000 gallons per diem may, or " may not, be pumped through the mains of the city, " but to calculate the available water supply from this " dividend, without previous deduction for the im- " mense escape of unavailable water by waste-pipes, or " otherwise, gives a most fictitious result. The large " waste which naturally arises in the system of inter- " mittent supply, has been well illustrated by some " evidence given by Mr. Lovick, before the late Metro- " politan Commission of Sewers, in respect of a par- " ticular block of nearly 1,200 houses.* Some of " the houses were of the higher, and many of the " poorer class, but the average might be stated to " be of the middle class, and to present a fair ex- " ample of an urban population. The drainage of " all these houses was discharged through one main " sewer. The run of water through this sewer was " carefully watched and gauged every hour, during the " night as well as the day, on days when the water " was on, that is to say, when the intermittent sup- " plies were delivered, and also on the ordinary days, " when the consumption of the houses was from butts " and cisterns, into which the intermittent supplies " were delivered. The gaugings of the discharge " of waste water into the sewer were checked by " gaugings of the consumption of water from the " butts and cisterns, during the interval of the delivery " of the supply by the Company. It was ascertained " that the average quantity discharged per diem " through the sewers was 44½ gallons per house; " but it appeared that on the days when the inter- " mittent supplies of water were on, the quantity " discharged per diem was 209 gallons per house. " The water in this district from defects in house " apparatus of distribution, incident to an inter- " mittent supply of water, was, on the water days, " 3¾ times greater than the consumption on " those days. No similar gaugings have, I believe, " been made within the city; so I am unable to tell " you with accuracy what are the proportions of " waste and consumption. In an interview with " your Committee on Health, when they were collec- " ting information on the subject, Mr. Mylne, the " engineer of the New River Company stated (as a " reason against fulfilling some object desired by the " Committee) that within the city of London, in con- " nection with its distributing apparatus, there existed " for the escape and waste of water, during the period " of supply, 'at least 10,000 open cocks.' Assuming " the accuracy of this statement, I doubt whether the " average available supply of water for domestic " purposes within the City can possibly exceed a " quarter of its alleged quantity; and I am persuaded " that there must be large numbers of persons to " whom the enjoyment even of that reduced average " is entirely unknown . . . . . On the extreme in- " convenience which attends the storage of water in " the poorer habitations of the City, I have already " reported to you, and will now only add that in- " creased experience has given much confirmation to " my view. Their receptacles are generally such as " contribute to the contamination of water, and are " constantly so arranged as to invite an admixture " of the most varied impurities. In the large " proportion of them, which are open casks, one " sees habitually a film of soot floating on the sur- " face; one sees (if indeed one can see so deeply " into water which is often turbid and opaque) " that filth and rubbish lie at the bottom; one sees the " interior of the cask itself dirty and mouldering. I " now merely glance at this part of the subject, because

* General Board of Health report on supply of water to the metropolis, page 120.

" you have already on other occasions allowed me to " state my knowledge at greater length. But there is " one evil in particular to which I would beg leave to " advert. Those works of drainage which are esta- " blished under your orders depend for their efficiency " on a proper supply of water; and in every case " where you enforce the construction of house drains, " you order that those drains shall be served efficiently " with water. Your wishes on this subject are nomi- " nally complied with by those on whom your orders " are served, but are often virtually evaded by a filthy " and ineffectual contrivance. The butt or cistern of " the house, that on which the inmates depend for " their supply of fresh and pure drinking water is " placed in immediate contiguity to the privy, so as " to reduce the requisite length of connecting pipe to " the fewest possible number of inches; the applica- " tion of water is not made discretionary on the users " of the privy, nor are any of the cheap and common " self-acting contrivances introduced; but the waste- " pipe of the butt or cistern is conducted into the dis- " charge pipe of the privy, so that, periodically, with " a frequency varying according to the arrangements " of the water company, the arrears of excrement are " removed, so far as the overflow of the water recep- " tacle may have power to dislodge and propel them. " Frequent evidence has been before me of the insuf- " ficiency of this arrangement, and, in addition to its " actual failure (on the reasons of which your surveyor " can speak more competently than I) there is strong " reason to object to its prevalence on other grounds. " Water, as you probably know, is a very active ab- " sorbent of many gaseous materials, and the open " butts, which are thus placed in immediate contact " and communication with privies, must rapidly be- " come infected by their foulness. I need not explain " to you how injurious an addition this is to the other " objectionable incidents of water-storage, or how un- " attractive as a beverage to the poor inhabitants of " the City must be this vapid, privy-flavoured stuff."

2747. Are you now speaking of London as a whole, or merely what is called the City of London?—When I speak of what I conceive to be the evils of the intermittent supply, I speak generally of it whether in the City or in London entirely, or in any other place. I look upon the intermittent supply as one which ought, if possible, to be got rid of.

2748. The long retention of water in leaden cisterns would render it unfit for drinking, would it not?—The long retention of water in any receptacles would make it disagreeable to drink.

2749. What is your opinion with regard to its being wholesome or unwholesome?—Hardish waters do not, I believe, under ordinary circumstances, derive much (if any) injurious impregnation from leaden cisterns, but it is undesirable, I think, that leaden cisterns should be in general use.

2750. You made use of the word "disagreeable" in your previous answer, and you say that water retained in any receptacle for a long time becomes disagreeable for drinking, which one can quite understand, but is it also unwholesome from that long retention?—Your Grace's question had reference to leaden cisterns, but waiving the question of what the nature of the cistern is, and looking only to the question of retention, water, so far as I know, does not thus become directly unwholesome; but I think it a great indirect unwholesomeness that water should be unacceptable to people, that the water of a great city should not be a nice water and pleasant to drink.

2751. You of course have analysed, and you are well acquainted with the quality of the London water?—Yes.

2752. What is your opinion as to its character?—Judging by chemical analyses, performed on it in what I may call its normal state, I am not aware that there is much fault to be found with it.

2753. You are speaking now of all the water supplied by the various companies?—Yes, speaking quite generally. Speaking of it in its broad ordinary chemical characters, as it would be reported on from a chemical laboratory, I should say it is a fair water supply.

2754. (*Sir B. Phillips.*) Are you now speaking of the whole supply of the metropolis?—Yes, speaking generally of it. But what I thus say of its average chemical constitution in its normal state does not touch the question of the water's liability to accidental very dangerous pollutions. There are dangerous qualities of water supply, with regard to which so far as I know (but I do not speak as a skilled chemist) chemists are totally unable to measure, even to demonstrate, the fatal influence that a water may have. A water may be, for instance, capable of spreading cholera, but chemists be unable to identify the particular contamination which produces that effect.

2755. (*Chairman.*) Have you any idea of the outbreak of cholera in any part of London having been caused by the quality of the water?—It is, I think, a matter of absolute demonstration that in the old epidemics, when the south side of London suffered so dreadfully from cholera, the great cause of the immense mortality there was the badness of the water supply then distributed to those districts of London.

2756. You mean the badness of the quality of the water?—Yes. In the interval between the 1849 epidemic and the 1854 epidemic, one of the two companies which supply the south side of London had amended its source of supply; it had gone higher up the river; and we at once lost a great part of the mortality on that side of the river. I may refer on this subject to a special report which I made in 1856 to the then General Board of Health, and which was laid before Parliament, on the last two cholera epidemics of London as affected by the consumption of impure water. I have just said that in 1853–4, after the one company had improved the quality of its supply, the southern district of London showed a greatly diminished liability to cholera. But it was found that this great difference did not prevail uniformly through the south side of London, but was confined to those houses which were supplied by the improved water supply. There was still great mortality on the south side of the river, but this belonged exclusively to the houses which were still supplied with impure water. The details of this gigantic crucial experiment, performed on half a million of people, are given in the report to which I have referred; this table, extracted from it, gives a striking synopsis of the results.

Death rates per 1,000 of living population in two epidemic periods.		In houses enumerated in 1854 as receiving their water supply.	
		From the Lambeth Company.	From the Southwark and Vauxhall Company.
Cholera	1848–9	12·5	11·8
	1853–4	3·7	13·0
Diarrhœa	1848–9	2·9	2·7
	1853–4	2·1	3·3

N.B.—Between the two epidemic periods the Lambeth Water Company had changed its source of supply.

Now we come to another epidemic period. And now fortunately both the companies which supply the south side of London, have ceased to give foul water. Subject to some qualifications which I will state presently, they both give fairly good water, and now, in consequence, the cholera mortality in those parts of London has been, comparatively speaking, insignificant. But, as is now matter of notoriety, within the area of another water company in London, the population last year suffered very dreadfully from cholera. I

J. Simon, Esq.

8 May 1867.

refer to certain eastern parts of London. Cholera in high development was confined to those parts of London, and those parts of London were in the area of one water company. And what makes this case the more remarkable is, that not the whole area of that water company suffered; the water company gave two waters, and the high cholera mortality was apparently restricted to those parts of London which received one of these two supplies.

2757. Which company was that?—It was the East London Company.

2758. (*Sir J. Thwaites.*) You stated that that company supplied two waters, and the black map (as you would call it) extended to that district supplied by one of those waters?—Yes, so to speak, to half the district of the East London Water Company. The source from which the company supplied this half of its district, was a source peculiarly exposed to contamination from a foul part of the river Lea.

2759. What was the nature of the contamination?—Sewage.

2760. And wherever that water was supplied there the cholera followed, did it not?—Speaking broadly for the whole metropolis, the area of intense cholera in 1866 was almost exactly the area of this particular water supply; nearly, if not absolutely, filling it; and scarcely, if at all, reaching beyond it.

2761. And there was a distinct line between the progress of the cholera, as marked by the supply of a superior water?—Generally speaking, yes. I lay two maps before the Commission which have been prepared for the Medical Department of the Privy Council Office, by Mr. Radcliffe, who has very elaborately investigated this epidemic. The maps (which will be published in my present annual report) sufficiently explain themselves.

2762. That impure water which you refer to was taken from the Lea?—Yes.

2763. (*Col. Harness.*) Do you also mean us to understand that a water might be productive of cholera, although it contained nothing which would be detectable by chemists?—Yes, I said something to that effect. A chemist would perhaps report that the water contained "organic matter," but "organic matter" covers an infinite variety of things, and he would have no means that I know for discriminating the organic matter which is really the ferment, the infectious material, of cholera, from a great number of other organic matters.

2764. He would distinguish the sewage organic matter from some other organic matters, would he not?—I am not quite sure of that.

2765. (*Sir J. Thwaites.*) When you speak of cisterns, you are of opinion, are you not, that lead should, as a principle, be avoided?—I think it very desirable that it should be avoided.

2766. But if water is of a certain degree of hardness, the mischief from lead would not be so great as if it were soft water?—Certainly not.

2767. When you speak of receptacles, and that water retained in them, although it might not be pleasant, would not seriously affect the health of the people, allow me to ask you this question: Having had great experience in the habitations of the poor, and the mode in which water is stored in filthy vessels often placed near to ashpits and privies, and other places where gases are generated, in your opinion, would not the tendency be that the water would absorb those gases and produce a zymotic effect upon those who used it?—Yes; but an answer to that is, of course, that the places ought not to have those stinks about them.

2768. We are now speaking of the constant as compared with the intermittent system of supply. Under the constant supply you would get rid of all those receptacles?—Yes.

2769. But under the intermittent system you must have the means of storage?—Yes.

2770. Have you a strong opinion upon that subject, that the water so retained in all probability would absorb gases which would be prejudicial to human health?—I have a very strong opinion that the water might absorb matters which would endanger health.

2771. (*Chairman.*) You are distinctly of opinion that it should be a constant supply as opposed to an intermittent supply?—I am strongly of that opinion.

2772. (*Sir J. Thwaites.*) You mean that the supply should be on the same system as at Philadelphia, New York, Nottingham, Preston, Glasgow, Newcastle, and Bristol?—Yes.

2773. In all those towns the constant system is, I believe, in operation?—I believe so.

2774. Have you heard of any difficulty that either of those towns has expressed in the application of the constant supply as compared with the intermittent?—I have understood that certain strict regulations are necessary, as between the water company and its customers, where the constant supply is given. And although I have not lately gone over the evidence on the subject, I am aware that the water companies allege great difficulties in giving a constant supply. I do not pretend to judge of the engineering part of the question; I speak only as to the desideratum for health. It is in the highest degree a desideratum for health that the supply be constant.

2775. Speaking generally, you are of opinion that the water would be in a better condition for the general health of the people under the system of a constant supply rather than of an intermittent supply, even disregarding the mechanical arrangements for storage?—Yes.

2776. You prefer taking it out of the pipes direct rather than having it stored in cisterns, whether properly constructed or ill constructed?—Yes, even assuming a good storage, still it would be better that it should be constant.

2777. Has your attention been directed to the quality of the water in London for drinking purposes, as to the effect upon the health of the inhabitants, as compared with water of a softer and purer character?—I have no evidence upon that subject. I think that, practically, the only very important sanitary question as regards the quality of the water supply to London is the question of organic admixture. I do not think that the question of a few grains of lime in a gallon of water can be regarded as a very important sanitary question.

2778. Then, in your judgment, the presence of lime, or two or three degrees of hardness in the water, would not be a matter of much consideration, supposing the water were free from organic impurities?—Quite so, as regards the public health.

2779. For drinking purposes, probably a little hardness in the water would add to its life and pleasantness to the taste?—I would not quite say that. I have found soft waters, or, at all events, hard water artificially softened, very agreeable.

2780. (*Chairman.*) Is it the case that when hard water is boiled it loses its hardness and becomes soft; I mean for washing purposes?—With some hard waters that is the case.

2781. Is that so with the London waters?—Yes, to a great extent.

2782. It has been stated in evidence that one of the great advantages of soft water, such as would be brought from Wales or the lakes of Cumberland, would be great economy in the use of soap in washing, do you agree with that?—I believe there is no doubt of that.

2783. We are told that soft water requires very little soap to get a very large quantity of lather, and also that a hard water when boiled becomes soft, but if when a hard water is boiled it becomes soft, is there much difference in the merits of the two waters; does the proportion between them still remain, with regard to the use of soap?—The soft water then stands in the same relation to the soap as if it had been originally soft, or comparatively soft; that is to say, its demerits in relation to soap are reduced, so far as the softening process extends.

2784. Both the hard water and the soft water being boiled, would you require less soap in the use of

the boiled soft water than you would in the use of the boiled hard water?—If by "soft" water you mean absolutely limeless water, such water cannot become softer by boiling, but on the other hand no amount of boiling, I believe, can quite perfectly soften the hard waters on which it is most effectual.

2785. (*Mr. Harrison.*) The system of putting quicklime into the water would reduce the hardness, would it not?—Yes. And it must not be lost sight of that that process of softening hard water in boiling is grievously at the expense of our apparatus; it furs our boilers, and gives a good deal of trouble in other ways.

2786. (*Chairman.*) Therefore that would be an answer, that a soft water boiled is better than a hard water boiled, although the hard water may become to a certain extent soft?—Yes.

2787. (*Mr. Harrison.*) And there would be the cost of the fuel to reduce it to soft?—Yes.

2788. (*Col. Harness.*) A water taken from chalk deposits the chalk in boiling, does it deposit it all?—I apprehend not.

2789. It is still a hard water?—Yes, as compared with distilled water or with a first-rate mountain water, such as some of the soft supplies which have been spoken of.

2790. (*Sir J. Thwaites.*) Speaking generally, if you had the choice of soft water compared with water of seven or eight degrees of hardness you would elect the soft water for general manufacturing and drinking purposes?—As regards many manufacturing uses, I believe it to be commonly conceded that soft water has very great advantages. As regards drinking purposes, I am not sure of any important difference, but am inclined to prefer the soft water.

2791. (*Mr. Prestwich.*) Do you know of any experiments which have been made with regard to the use of soft water and hard water upon health?—If by hard water is meant such water as we have in London, I am not aware of any facts of the smallest value showing difference of effect between such water and soft water.

2792. It has been stated that there are certain classes of diseases more prevalent in districts where hard water is used than in others, for example, diseases of the bladder and the stone; can you give us any evidence on that point?—I do not think there is any evidence that is worth a rush upon that subject.

2793. That evidence which was given by Dr. Prout some years ago, you do not attach much importance to?—I do not remember the exact language of Dr. Prout upon the subject, nor know whether he professed to argue from any large field of observation; but I believe that no statistics of value exist in proof of such an assertion.

2794. (*Chairman.*) Is it true that diseases of the bladder prevail very much in Norfolk?—It has been said so, and of course there have been many explanations, among which Norfolk dumplings hold a chief place; but when that assertion became current, Norwich had a famous lithotomist. It is possible that his reputation, by attracting sufferers into temporary residence in the district, or perhaps his zeal in discovering cases of stone, may have given the district a fictitiously lithogenous character.

2795. (*Sir J. Thwaites.*) Has your attention been directed at all to the system of filtration of the Thames water?—It has been generally directed to it, but I cannot say that I have recently tested the results; I have not confidence in the sufficiency of the filtration to a degree that would, if I may quote my own case, lead me to dispense with having a charcoal filter in my own house; I draw all my water through a charcoal filter.

2796. I presume that the filtration adopted by the water companies would simply take out that which is held in mechanical suspension, but all that is held in solution must pass through unaffected?—When a filter is fresh and clean, it would effect also some amount of chemical conversion of the dissolved matter, but filtration, as enforced on water companies, ought not, I suspect, to be relied upon for the separation of anything beyond gross mechanical impurities.

2797. Not so much as if the water passed through charcoal?—No, certainly not.

2798. (*Mr. Prestwich.*) Are you aware that any experiments have been made at St. Thomas's Hospital or at any public establishment with regard to the quantity of water required per head in such establishments apart from waste?—I am not prepared to quote any observations of that kind, but I observe that in my City Reports to which I have already referred, I said the average of requirement for the general population might in my opinion reasonably be estimated at about 12 gallons per person per diem.

2799. Have you seen any cause to alter that estimate?—I have never since had occasion to go into the subject as thoroughly as I went into it then. I then took a great deal of pains with it, and got what evidence I could about it, of which I only submitted the general result. The estimate there given is the best that I could then form. Probably there are better means now than existed then of judging in the matter.

2800. Would that estimate refer to the wants of the individual, or does it take the average including the quantity used for public supply?—It was exclusive of what was wanted for public supply.

2801. Including the public supply what should you consider the quantity required per head of the population for all purposes?—I have no special means of judging what quantities would be wanted for sewers and street-watering and fires.

2802. (*Chairman.*) It has been variously stated between 25 and 50 gallons?—I hardly know what means there are of estimating it per head, except the actual supply of the companies. The great quantity of waste which there is in the present supply makes the conclusions uncertain. There must be an enormous waste.

2803. You think that a constant service supply without those pumps and standcocks and so forth would lead to a very much more economical use of water?—I think so.

2804. (*Sir B. Phillips.*) Did I understand you correctly in the earlier part of your examination to say that you considered the quantity of water supplied to London to be good?—Yes, fairly good, if considered apart from the question—which I reserve as quite a special one—of organic admixture.

2805. You mean that the water itself is good?—Yes, I think it in its natural state to be fairly good.

2806. You have also stated that that did not exhaust the question, because if I understood you rightly there might be particles in the water which no chemist could discover and which might tend to produce certain diseases?—That is so.

2807. I apprehend that that observation (I am now asking of course what may be a scientific question) does not only refer to the water supply of London, but the same observation would refer to any other water from any other source?—Undoubtedly, and yet I think that perhaps you are a little misunderstanding what I mean. I mean that the question of good supply or bad supply is not to be judged only by what the chemists from their laboratory can tell you of the water. The greater part of the water supply to London, as you are aware, is pumped from the Thames. That portion is taken from the Thames after a million of population has drained into the river. Nothing which chemists in the present state of their science can report (negatively) as to their findings in London water will alter the fact of that filthy admixture. And I know that that fact represents a certain amount of danger to the population that receives the water.

2808. Then that danger is not discoverable by chemists?—I do not know that chemists could have discovered the infectious quality which is believed to have existed in the East London water supply in the beginning of last July. I do not know that chemists could have identified it, or could have come down

J. Simon, Esq.

8 May 1867.

upon it as they would come down upon arsenic or copper.

2809. Then if it could not be discovered you only presume that it might be so?—We trace the sewage into the water, we trace the water into the district, and we trace the inhabitant to his cholera and death.

2810. (*Mr. Prestwich.*) I think you mean to say that although you detect in this water the presence of organic matter, you cannot detect whether this organic matter is or is not of a more or less poisonous quality; that is to say, whether it bears the germs of any particular disease?—Quite so.

2811. Would not the presence of organic matter in water give rise to suspicion?—Yes.

2812. But you have not been able in all those cases of suspicion to trace the cause of the evil which has arisen from the use of those waters?—There are certain organic matters in water, peaty matters for instance, as to which I do not know of my own knowledge that they do any harm. I think it would be safer that water should be without any organic mixture, but with regard to some of those matters we do not know that they do harm. The water which has done very great harm in London on various occasions, as we believe, has been water conveying what by a figure of speech I may call the actual seeds of specific disease. Chemists cannot identify those seeds. Whether microscopists can, is a question which is likely, within the course of the next 12 months, to be settled: at the present moment there is a belief amongst some very competent persons that such water would contain demonstrable microscopical organic germs, each carrying an infectious power. My practical point is, that what one has to do is not to take water out of a reservoir or out of a tap and give it to a chemist and say, Tell me is this wholesome water. What one has to do is to guard the supply with the utmost strictness against every foul admixture. It ought to be made an absolute condition for a public water supply, that it should be incontaminable by drainage.

2813. (*Chairman.*) Then whatever appearance the water had when it arrived at a house, if you knew that it had been contaminated before it was taken into the pipes of the company, you would assume that that water was bad?—Yes.

2814. (*Sir B. Phillips.*) Do not you think that the main drainage is likely to rid us of a great deal of the river impurities?—The main drainage will do a great deal for us, but you will observe that our water supply, for a great part of London, is drawn above Teddington lock, and the main drainage of London, would not, of course, do anything for that. Above that point a million of population drains into the river.

2815. (*Mr. Harrison.*) Are you aware of the Act passed last session giving power to the Commissioners of the river Thames to compel all the towns on its bank to do away with the discharge of their sewage into the Thames?—Yes, it is a most important power, and I hope it will be vigorously exercised.

2816. Are you aware also with regard to the river Lee, that a report was presented to the House of Commons within this week from the Rivers Pollution Commissioners, who have recommended the same course with regard to the Lea; namely, absolute compulsion as to all the towns taking their drainage away from the Lea?—I have not seen that report, but I knew that such a one was about to be made.

2817. But assuming that the power given to the Commissioners of the River Thames conservancy are fully carried out, which amount to an absolute prohibition as to the towns drawing their sewage directly into the Thames, would not that, in your opinion, be an immense advantage in purifying the present supply of London which is taken now above Teddington lock?—Yes, it would be a very great gain.

2818. Supposing that the prohibition were extended to all sewage going directly into the river at any part of it, and that under the powers which are given to the Thames Conservancy Board, they compelled the towns to distribute their sewage for the purposes of irrigating the land, and consequently that all the water falling on the surface merely came into the river after having passed through the soil, do you think that in that case the Thames water taken above Teddington lock would still be polluted, or should you consider it to be practically free from pollution?—Assuming a sufficient thickness of soil, I should so consider it.

2819. Can you form any opinion at all in that case as to whether the water taken above Teddington lock would still be impure and unwholesome supposing, for instance, it had travelled exposed to the atmosphere for 15 or 20 miles of river?—I should think it quite a safe water as regards the danger that we are speaking of.

2820. Supposing that Parliament adopted the recommendation which I know to be the result of the inquiry on the river Lea, by which all the towns upon that river should be compelled, upon the same principle as they will be on the Thames, to keep their sewage entirely free from the river, would you not then consider that, as far as the Lea is concerned, the water coming chiefly as it does from the chalk would be a good and wholesome water for the supply of London?—Yes, very good; but the dreadful mischief which is believed to have resulted from the badness of the Lea supply last year is not, so far as I know the facts, attributed to water derived directly from the company's avowed sources in the river Lea, but is attributed to the reservoirs having to some extent received water from a part of the Lea which is not avowed as a source of supply, and is in fact the common sewer of a large mass of metropolitan and suburban population. The avowed sources of the company's supply are high up the Lea, where the impurities are, comparatively speaking, scanty; but the Old Ford reservoirs of the company adjoin the river Lea in a part of its course where it is extremely foul. There were facilities for the passage of this foul water certainly into one set of reservoirs, and probably into another set of reservoirs, and it is believed to have been this admixture of foul water, which conveyed the seeds of cholera into the supply.

2821. (*Sir J. Thwaites.*) Do you mean from one of those stagnant cuts in that neighbourhood?—Yes.

2822. (*Mr. Harrison.*) Taking generally the question of the large extent of the Thames, and taking the fact that the water beyond all question is first absorbed into the chalk and then flows out again into the Thames, you do not see that there is anything objectionable in the water of the Thames basin itself?—Apart from sewage admixture and pollutions certainly not, looking upon it in its natural state.

2823. Although it is a hard water, in some cases to even 18 or 20 degrees, yet that would not be in your mind, in a sanitary point of view, objectionable to use that water?—It would not make it unwholesome water, so far as I know, for drinking, but there would remain of course the economical question.

2824. Therefore we may assume that the question, as between the existing water in the Thames basin and pure soft water, would be practically reduced to its economical results for the purposes of washing and culinary purposes and domestic use?—Yes, and the question of a quantitative sufficiency; whether the Thames would give enough water.

2825. As far as the simple sanitary question goes, you see no objection at all to it?—No.

2826. Therefore it is reduced simply to the question of economy, as between the use of soft water and hard, assuming the sewage to be kept free from it?—I think so.

2827. With regard to the constant supply, there is a great difference of opinion as to whether it ought to be by cisterns, or whether the water should be taken directly from the pipes. Are you aware whether in the towns which you have mentioned, where the supply is constant, any uniform system has been adopted?—I am not able to speak off-hand upon that subject, it is long since I looked over that part of the question.

2828. Still, in all those cases where they have what

professes to be a constant supply, they are liable to the accidental bursting of pipes, and, occasionally, for some time to be without a supply?—Yes, but cisterns do not give security against accident.

2829. But your chief object would be by having the water direct from the pipes without cisterns to avoid any stagnation of water that might take place, and the accumulation of dirt or filth in those cisterns?—Yes, and to avoid, as regards the immense masses of the poorer population, the expensive necessity of storage.

2830. As I gather from your report, as regards the poorer parts of London you attribute even more importance to having a constant supply than the other part of the question?—Yes. It matters very little, of course, to people who have money and large houses whether they have cisterns or not, but to the poor it matters immensely. For many years I have had nothing to do with the details of those local administrations, but when I had to do with the city of London as officer of health, it struck me that almost the most important reform that was wanted in the sanitary circumstances of the poor was the substitution of the constant for the intermittent water supply.

2831. That you would look upon as really affecting the health of the poorer classes, perhaps, to a very much larger extent than their having an abundant supply of water both for cleanliness and washing their clothes, and every thing in connexion with it?—Yes.

2832. In the present state of London that is really one of the great deficiencies that they have to labour under in the poorer parts?—Yes. I cannot conceive of a person who knows the difference between decent water and other water drinking such stuff as would be drawn out of a butt in the city.

2833. Are you aware of any statistics that have been taken within the last year or two in the city of London, in any of the model lodging-houses and other places, as to the actual consumption of water where they have had an unlimited supply?—No, I cannot give information upon that point.

2834. Then taking the question of soft water, even taking the purest, which I suppose is that supplied to Manchester, can you give any idea at all as to the value which you attach to it as a pure question of economy as between soft water and hard water?—What little information upon that subject I have had has been derived from others. I have never made any local inquiry about it; but such information as I have derived, for instance from Mr. Bateman, would lead me to think that the saving is very great and very important.

2835. Having at your door a soft water or hard water, you would give a decided preference to soft water, taking all questions of economy and health into account?—An overwhelming preference with regard to economy; about that there can be no doubt. And as regards health my bias is in favour of soft water, but I cannot say that I think the case established against hard water (i.e. against hard water of such comparatively few degrees of chalk hardness or carbonate of lime hardness as you have in the London waters) that it acts injuriously on health. It is different, of course, when you come to certain other hardnesses of water; but I do not think that the hardness, for instance, of the New River Company's water can be considered detrimental to health.

2836. (*Chairman.*) What is that hardness measured by—degrees?—It was 16 last week in the Registrar-General's returns.

2837. (*Sir J. Thwaites.*) When you speak of the interception of sewage flowing into the Thames, and the general power of the Thames Conservancy Board to accomplish that object, the Thames itself would be a proper source of supply to the metropolis; but have you, apart from the question of sewage, considered the condition of the Thames basin as a gathering area, having regard to the high state of cultivation of the land and the use of manures, artificial and other, and the washing of water into the Thames, what the effect upon the water would be for domestic purposes?—The earth is a most powerful absorbent and disinfectant of the materials used as manure, and I do not think that practically any important danger would attach to the outflow from cultivated lands.

2838. (*Chairman.*) The sewage of towns, I conclude, is what you would fear most?—One would not wish in these matters to draw very minute distinctions: one would wish to keep all sorts of nastiness out of the water: but the tremendous danger to the population is the introduction of human sewage with the germs of contagious disease in it. It is of course an entirely new thing in the history of the world, this power that water companies have, to distribute the germs of disease in that way. One single water company distributes its supply to perhaps half a million, or more, of population. The danger is enormous if such a supply is drawn from sources near dense population, or sources in any other way contaminable by sewage. This power of life and death in commercial hands is something for which till recently there has been no precedent in the world, and even yet the public seems but slightly awake to its importance.

2839. (*Sir J. Thwaites.*) Supposing that those upper towns are driven to deodorise their sewage, or to apply it for irrigation to the land, would the water that must pass off ultimately into the river be sufficiently purified, do you think, so as not to affect the river prejudicially?—A speculative answer is not worth much upon this subject, and I can only give a speculative answer at present. I think it very likely that the water would be harmless, but possibly the result might show that the water could not be deemed quite safe.

2840. Have you examined the water at Croydon as it passes into the Wandle by a culvert after the sewage has been applied to the land; have you observed that it is perfectly clear and colourless, and yet it holds in solution a vast amount of deleterious qualities?—I have not examined it, but in a report which I have recently received on the subject the following statement is contained: "At Beddington, 1,000,000 "gallons a day have now been employed for some "years to irrigate 310 acres of land. There are no "complaints of injury to the neighbourhood, and the "agricultural value of the land has much increased, "the sewage being productive of equally good results "in dry and in wet weather. The sewage, after "passing over the land, contains just one grain of "total impurity more than the water of the Croydon "Waterworks—22 and 23 grains to the gallon; here "the soil is porous gravel. At a second outfall at "Thornton Heath, 250,000 gallons daily are used on 20 "acres of land where grass and market produce are "grown, and for most crops it is found to give re-"markably favourable results; here again the soil is "gravel. At a third outfall in Beckenham parish 37 "acres of stiff clay soil are irrigated, and the largest "and healthiest crops of all to which the sewage is "applied are got from this clay soil, a circumstance "that was not expected, while the purity of the "effluent water is almost absolute." Speaking generally of places where land is manured, there can be no doubt whatever that, with a certain intensity of manuring and a certain smallness of area, the water at the outflow would be still loaded with putrescible organic matters; but whether the manuring in the Thames basin would be of that sort, whether it would be so intense in proportion to the area that the river water would be still putrescible, is, I think, doubtful. I should have thought not, but as I have said it is not a matter upon which a speculative opinion is worth anything. Of course the same conservation of the river as purports to provide against direct infusions of sewage ought to provide also against every influx of tainted land-drainage.

2841. (*Col. Harness.*) The nature of the soil through which it passed would affect it, would it not?—Yes, very much indeed.

J. Simon, Esq.
8 May 1867.

2842. (*Mr. Prestwich.*) And the nature of the flow of the river also?—Yes.

2843. In considering the question of constant supply, would not it be an important point that the water to be so delivered would be generally cooler and fresher water than that which is now delivered on the system of intermittent supply?—I look upon that as of very great importance indeed. I do not think it has been half enough considered how important it is that the water of a great city should be pleasant for drinking.

The witness withdrew.

Dr. W. Farr.

Dr. William Farr examined.

2844. (*Sir J. Thwaites.*) You are, I believe, a Fellow of the Royal Society and Superintendent of the Statistical Department of the General Register Office?—Yes.

2845. Has your attention been directed to the supply of water, and the quality of water and its effect upon the health of the people?—It has for many years.

2846. And especially within the metropolis?—Yes.

2847. Are you able to give the Commission any information as to the present supply, and how it affects the health of the metropolis?—With regard to the importance which I attach to the water supply, I made a representation to the Registrar-General after the cholera epidemics of 1849 and 1854, which led to his getting the waters of London analysed regularly by Dr. Robert Dundas Thompson in the first instance, and latterly by Professor Hofmann and Professor Frankland, of the Royal College of Chemistry.

2848. Since Professor Hofmann left England, have you had anyone associated with Dr. Frankland?—No; Dr. Frankland succeeded Professor Hofmann at the Royal College of Chemistry, and he naturally continued the analyses.

2849. Does he continue to make monthly analyses of the water?—Yes, and this is the one published to day (*handing in the same*).

2850. In this analysis of Dr. Frankland the Chelsea, West Middlesex, Southwark, Vauxhall, Grand Junction, Lambeth, Kent, New River, and East London waters appear to be contrasted with the Loch Katrine water?—Yes.

2851. Is that Loch Katrine water taken to be the standard water now?—We consider it to be one of the best standards, and remarks are made on it in the weekly return of to-day, which I will read to the Commission, "Loch Katrine water is an instance of the "purest water in actual use in a great city: in 100,000 "parts there are only three parts of extraneous stuff; "except this all is water. The London waters of "April contained according to Dr. Frankland's "analysis in 100,000 tons about 29 tons of extra- "neous matters of various kinds; the proportions "ranging from 26 tons in the New River water to "40 tons in the water supplied by the Kent Com- "pany." That is for determining merely the amount of extraneous matter. For testing the hardness, Dr. Frankland adopts the process suggested by Dr. Clark, on a different scale however, and he shows in the analysis of April last that the hardness varies from 16 degrees of hardness in the East London water to 21 degrees in the Kent Company's water, and the Thames Companies' water varies from about 16 to 18 degrees of hardness. Then Dr. Frankland has latterly extended the analysis so as to determine the amount of organic carbon as he calls it, and the amount of nitrogen in those waters.

2852. What does he mean by organic carbon?—Carbon which has recently existed in some organic body, either animal or vegetable. He finds that in the water and he compares it with the quantity that would be supplied by sewage of an average degree of dilution, estimated I think by Professor Way. He finds that the proportion of carbon and nitrogen was equivalent to that supplied by a quantity of sewage ranging from 1,945 to 3,155 tons in every 100,000 tons of water. It is therefore gratifying to learn that as far as chemistry can determine the original sewage contamination had been converted into comparatively innocuous inorganic compounds before its delivery to the consumers. It is Dr. Frankland's opinion that all those organic matters which probably would have been injurious if supplied directly to the population have undergone changes in the earth, in the rivers, and in the filters of the companies.

2853. What was the time occupied in producing that chemical change?—Dr. Frankland states here that he has taken those waters from the mains, and not from the butts. He finds that those substances existed in the water, but that they are changed into nitrates and nitrites and ammonia, and that they are no longer in a state of sewage.

2854. And therefore not injurious to human beings?—Not injurious to health.

2855. (*Mr. Harrison.*) That analysis refers to the month of April does it not?—Yes; I merely cite this to show the present system of analysis in operation.

2856. (*Col. Harness.*) He does not attempt to lead one to assume any period that has elapsed since it was in contamination with the sewage, but merely that it has at some period been in contact with sewage?—It contains the amount of those ingredients which would be supplied by those amounts of sewage at some time or other.

2857. (*Sir J. Thwaites.*) As I understand the result of the analysis made by Dr. Frankland is that he detects the presence of sewage broken up by a chemical change into other compounds, and that although in its concentrated form as sewage it would be injurious to the public health, yet now in its altered chemical condition it is not injurious to the public health?—That is so.

2858. What I want to know is whether Dr. Frankland's attention had been directed to the time occupied in the transformation of this sewage into the several elements referred to by him?—He does not mention that. Perhaps I have not stated quite correctly what Dr. Frankland says. He says that he finds those amounts of organic carbon and nitrogen in the London waters, and then to give us an idea of the original degree of impurity he says what amount of average sewage would produce that amount of nitrogen and carbon, and according to his estimate if 1,945 tons of sewage had been poured out at any time into the waters which the Southwark and Vauxhall Company supply, it would have given the result which he detects by chemical analysis on the 12th of April. He takes that water from Barclay's brewery on the 12th of April, he finds certain substances, nitrogen and other substances, the quantities of which he determines, and then he says that those quantities are equivalent to the quantities that would be produced by sewage of an average degree of impurity.

2859. Is there anything in Dr. Frankland's return to show that if sewage discharged into the river at point A is conveyed through a large volume of water some few miles down the river, becoming exposed to the atmosphere from time to time, as the effect of that exposure the sewage might become broken up into elements that would not be offensive, and, in point of fact, it would become deodorised and purified by the action of the atmosphere, so as to be rendered innocuous?—I would rather express my own opinions than attempt to express Dr. Frankland's, as I am not in possession of all his views.

2860. What is your opinion upon the subject?—This analysis is only taken once in the month, and we have found that the excellent use of it has been to keep the water companies on the alert, but it necessarily does not determine the variable quantity of impurity in the waters. It may happen, for instance, that on

April the 11th, the sewage, instead of being all converted into innocuous matters, might have been in a state so as to be injurious to health.

2861. But have you, in the interests of health, instituted any inquiry as to the chemical result of sewage poured into a river and being conveyed in the natural volume of that river some few miles and exposed to the atmosphere, so as to be able to speak to its condition at the end of the stream?—I have not done so; that, of course, is a purely chemical inquiry. There have been chemical analyses of the water, and it certainly does undergo transformations, but I apprehend that the eggs of worms or the seeds of disease in some way would often remain unchanged.

2862. (*Mr. Harrison.*) This is the point, I think, to which you refer in the report of Dr. Frankland: "By gradual oxidation, partly in the pores of the "soil, partly in the Thames or its tributaries, and "partly in the reservoirs, filters, and conduits of the "Chelsea Company, this sewage contamination has "been converted into comparatively innocuous, inor-"ganic compounds before its delivery to consumers." That is Dr. Frankland's report for the month of April. —Yes. I mean to state that it is my opinion that the quantity of those matters thrown into the river varies very much. It depends very much upon the floods and the rainfall, and so on. It is a fluctuating quantity, and it might, and it generally is, I believe, reduced into that innocuous form, but it might also be brought down in a form that would render it unsafe.

2863. (*Sir J. Thwaites.*) Rivers, of course, have a power of their own, and nature has a power of its own, to purify the water by exposure to the atmosphere, and the question which I put to you is, whether that power would operate so as to purify water that might be affected by the discharge of sewage into it?—I should not think it would invariably; it might frequently do so, but it would depend upon the quantity that was poured into the river, and also upon the temperature. The condition of the organic matter in the river will vary according to the temperature. As you will remember, the state of the Thames was very different when the temperature was high from what it was when the temperature was low.

2864. Do you recollect the experiments at Leicester, where the river became so impure from the discharge of sewage into it that for 3 or 4 miles the fish were destroyed, and plants also, but at the end of that fourth mile, I think, plants began to revive, and the fish also, and the stream assumed its natural condition?—I recollect something of that kind, but I could not state it as evidence of my own. However, I have no doubt that it is a general truth.

2865. Having regard, therefore, to the condition of the London waters, do you attribute the outbreak of cholera in the eastern division of the metropolis to the water supplied to those districts, or to any other cause? —The epidemic of cholera broke out in London, as you are aware, last year, about July. It had been prevailing in different countries in Europe, and happened to reach this country then. Of course my attention was directed to it. We watched its progress in London, and I have here a series of papers which I can put in, if the Commission would like to have them. They are extracted from the Registrar-General's weekly return, and contain all that he states on the progress of the epidemic. I would call the attention of the Commission particularly to the return of the week ending July 28th last year. Cases of disease had occurred in certain numbers in the beginning of July, but there was nothing decisive until July the 14th, when these remarks occur in the weekly table: "The intense heat "of the weather has favoured the development of "diarrhœal disorders. Diarrhœa was fatal in 150 "cases; and 32 deaths by cholera are recorded in the "week, of which 2 were in the west, 4 in the north, "3 in the central, 20 in the east, and 3 in the south "districts. About half of the number are cases of "death by choleraic diarrhœa, or summer cholera," and those cases are given. Then it says, "Immediate "measures should be adopted by house to house visi-"tation, and otherwise, to treat the disease in its "earliest stage of diarrhœa, and the cholera excre-"tions should be effectually removed or destroyed." We saw at once that there was likely to be an outbreak of the epidemic in London. The number in the next week increased from 32 to 346. "Of the 346 fatal "cases now recorded, 308 occurred in the east dis-"tricts of the metropolis." I will describe very briefly the state of things existing in the next week ending July the 28th. "The deaths registered in London "during the week were 2,600. The deaths in the "present return exceed by 1,213 the estimated num-"ber." That was quite alarming, and it was the first decisive display of the force of the epidemic. "The "excess of deaths is caused entirely by cholera "and diarrhœa; 904 deaths by cholera, 349 by "diarrhœa, were registered in the week, making "in the aggregate 1,253 deaths." We saw how they had run up from 6 to 14, 32, 346, and 904 by cholera. Then as to locality, "It is a pecu-"liarity of the case that a greater part of this "slaughter in seven days of 1,253 people of all ages "took place within a limited portion of the London "area. 924 of the deaths, 811 by cholera and 113 "by diarrhœa, were registered in the six districts of "Bethnal Green, Whitechapel, St. George's in the "East, Stepney, Mile End Old Town, and Poplar, "including Bow, among about a seventh part of the "population of London, and on one-fourteenth of its "area. The attack extends all along the north side "of the Thames from the river Lea and the Isle of "Dogs to the Tower of London; Limehouse Basin "and the Regent's Canal are the central line of the "attack, which stretches as far north as Victoria "Park. This is essentially the port of London, in-"habited by its maritime population. The canals "and the basin are full of foul water, and are appa-"rently connected with the Limehouse Cut, the "Hackney Cut, and the river Lea. The East London "Waterworks canal draws its supply from the river "at Lea Bridge, where there is a reservoir, and runs "for a couple of miles by the side of the Hackney "Cut down to its other reservoirs north of Bow and "near the Lea. The present cholera field derives its "waters from these works. It is right to add that "the water has hitherto borne a comparison with the "other London waters in Dr. Frankland's analyses. "To-day at Poplar the water looks clear, and no "complaints are made of its quality. The company "will no doubt take exemplary pains to filter its "waters; but it is not easy to guarantee the purity "of water drawn from such a river as the Lea, in "dangerous proximity to sewers, cuts, and canals."

2866. Did you observe any filtration from those cuts?—I went down to this district on the Monday before writing this report, and went round to a great number of the houses where the people were suffering, and I noticed the dangerous effect of the waterbutts there. Then the return goes on to say, "Whoever "will take the trouble to go among the people now "suffering in crowded dwellings, will see the danger "of the waterbutt; poor women are washing the "dirty linen of patients with water drawn from those "vessels, which are often found close to the water-"closets. It would be a source of additional safety "to London, if the tanks and butts were all abolished, "and the pipes were filled on the system of constant "supply. The time has come for this reform." We have all along been convinced of the importance of the constant supply, so as to get rid of those evils which are of course most felt in the houses of the poor, where they have not the conveniences that the rich enjoy. "The mortality is overwhelming in "some of the districts. In Poplar alone 145, in Bow "188 people died last week, including Dr. Ansell, "the meritorious health officer, and Mr. Ceeley, clerk "to the Board of Works, whose name figures on the "placards. The people are falling ill every hour; "you see them of all ages, children and adults, lying "about their beds like people under the influence of "a deadly poison, some acutely suffering, nearly all

r. W. Farr.
May 1867.

"conscious of their fate and of all that is going on around them. Here the doctor is drawn in by the husband to see the wife now attacked; there the husband lies in spasms; here is an old woman seated dead with eyes wide open; there lies a fine four-year old child, his curly head drooping in death, but his mother says the pulse is strong and he takes what she gives him; an older brother, just recovered, is running about. Several wards of the London hospitals are full of patients, many of them very young children in all stages of the disease; some dying, some well again and playing. The medical men have no rest, and with the health officers are nobly doing their duty; brave men ready to lay down their lives for their patients. The people themselves are most patient, most willing to help each other, the women always in front and none shrinking danger. There is no desertion of children, husbands, wives, fathers, or mothers, from fear. In the midst of this scene, the authorities have been to some extent paralysed. The nuisance inspectors are not sufficiently numerous, neither are the medical officers. The administrative work has not been organized with sufficient promptitude, and is not carried out with sufficient energy. Such a calamity as this may well call forth the whole resources of London, and what is especially wanted is executive power well organized in conjunction with the medical health officers. The people of East London want help." The Commission will see from that how we came to the conclusion that the great mortality of those particular districts was caused by the distribution of impure water. I will hand in a table, which I will ask the Commission to look at.

POPULATION and WATER SUPPLY of SUB-DISTRICTS, also DEATHS from CHOLERA, in each of the Three Weeks ending 28th July 1866.

Water Company furnishing chief Supply.	Registrars' Sub-district.	Population, 1861.	Deaths from Cholera in the week ending Saturday, July 14 1866.	July 21 1866.	July 28 1866.
	WEST DISTRICTS.				
G. Jun. & W. Mid.	St. Mary, Paddington, *W* H	39015	–	1	1
Grand Junction	St. John, Paddington, H	36769	–	–	1
West Middlesex	Kensington Town, *W*	51910	–	1	1
W. Mid. & Chel.	Brompton, H	18198	–	–	1
W. Mid. & Wells	St. Peter, Hammersmith	5415	–	2	2
W. Mid., G. Jun., and Wells.	St. Paul, Hammersmith	19104	–	5	–
W. Mid., Chelsea, & Wells.	Fulham, *W*	15539	–	2	1
Chelsea	Chelsea, South H	21654	–	–	1
Ditto	Chelsea, North-west, H *Ww*	19899	–	–	–
Ditto	Chelsea, North-east	21886	–	–	–
Grand Junction	Hanover-square	19773	–	–	–
Ditto	May Fair, *W*	12885	–	–	–
Chelsea	Belgrave, H	55113	1	–	2
Ditto	St. John, Westminster	37483	1	–	1
Ditto	St. Margaret, West., *W* H	30730	–	–	–
New Riv. & Chel.	Charing Cross, *W* H	11071	–	–	1
New River	Long Acre	11618	–	–	–
Ditto	Berwick-street	10607	–	–	–
Grand Junction	St. James's-square	10753	–	–	–
Ditto	Golden-square, *W*	13966	–	–	–
	NORTH DISTRICTS.				
West Middlesex	All Souls, Marylebone, H	29952	–	–	1
Ditto	Cavendish-square	15090	–	1	–
G. Jun. & W. Mid.	Rectory, Marylebone, *W*	26692	–	1	1
Ditto	St. Mary, Marylebone	22493	–	–	–
West Middlesex	Christchurch, Marylebone	34913	–	–	1
Ditto	St. John, Marylebone	32540	–	–	–
N. Riv. & W. Mid.	Hampstead, *W*	19106	–	–	–
West Middlesex	Regent's Park, Pancras	34927	1	–	–
N. Riv. & W. Mid.	Tottenham-court, *w*H	29371	–	–	–
New River	Gray's-inn-lane, H	27808	–	–	1
Ditto	Somers-town	39099	1	–	2
New River	Camden-town, *W*	23266	–	–	4
Hampstead	Kentish-town	44317	–	–	3
New River	Islington, West, *W* HH	75442	1	–	1
Ditto	Islington, East, *Ww*	79899	1	–	1
Ditto	Stoke Newington	6608	–	–	–
East London	Stamford-hill	5483	–	–	1
New River	West Hackney	24265	–	–	1
E. Lond. & N. Riv.	Hackney, *W* H *w*	31481	–	3	–
East London	South Hackney, L	15458	–	1	3
	CENTRAL DISTRICTS.				
New River	St. George, Bloomsbury	17392	–	–	1
Ditto	St. Giles, South, *W*	19483	–	–	–
Ditto	St. Giles, North	17201	–	–	–
Ditto	St. Anne, Soho	17426	–	–	–
Ditto	St. Mary-le-Strand	1034	–	–	–
	CENTRAL DISTRICTS—*cont.*				
New River	St. Clement Danes, H	15267	–	–	1
Ditto	St. George-the-Martyr, H	19903	–	–	–
Ditto	St. Andrew, East, Holb., *W*	12947	–	–	–
Ditto	Saffron-hill	12012	–	–	–
Ditto	St. James, Clerkenwell, *W*	19152	1	–	–
Ditto	Amwell, Clerkenwell	17250	–	–	1
Ditto	Pentonville	13079	–	–	–
Ditto	Goswell-street	16200	1	–	1
Ditto	Old-street	11504	–	–	–
Ditto	City-road, HL	17860	–	–	1
Ditto	Whitecross-street	14778	–	–	–
Ditto	Finsbury	12931	–	–	1
N. Riv. & E. Lond.	St. Botolph, East London	20990	–	–	4
New River	Cripplegate	19597	–	–	1
Ditto	West London, North, *W* H	11750	–	1	1
Ditto	West London, South	15395	–	–	1
Ditto	London City, South-west	7762	–	–	–
Ditto	London City, North-west	9020	1	–	–
Ditto	London City, South	8570	–	–	–
Ditto	London City, South-east	8659	–	–	–
Ditto	London City, North-east	11544	–	–	1
	EAST DISTRICTS.				
N. Riv. & E. Lond.	Holywell, Shoreditch	17343	–	1	5
New River	St. Leonard, Shoreditch, L	19188	–	–	1
Ditto	Hoxton New Town, *w*	26516	1	3	1
Ditto	Hoxton Old Town	25777	–	–	–
East London	Haggerstone West, *W*	23250	1	1	–
Ditto	Haggerstone East	17510	–	–	–
Ditto	Hackney Road	26398	–	3	8
Ditto	Green, Bethnal Grn. *W* HL	31789	2	30	49
Ditto	Church, Bethnal Green	25528	1	8	18
Ditto	Town, Bethnal Green	21486	1	2	15
E. Lon. & N. Riv.	Artillery, Whitechapel	6557	–	2	1
East London	Spitalfields	15700	–	–	9
Ditto	Mile End New Town, *W*	15392	–	7	25
E. Lon. & N. Riv.	Whitechapel North	12122	1	2	9
East London	Whitechapel Church, H	8062	1	8	70
Ditto	Goodman's Fields	11166	–	5	12
N. Riv. & E. Lond.	Aldgate	9971	–	1	5
East London	St. Mary, St. Geo. East	18181	–	10	26
Ditto	St. Paul, St. Geo. East	21045	1	8	23
Ditto	St. John St. Geo. East, *W*	9295	–	7	30
E. Lon. & N. Riv.	Shadwell, *W*	12567	–	10	22
East London	Ratcliff, *W*	16874	2	14	38
Ditto	Limehouse, *W*	27161	4	43	75
Ditto	Mile End Old Town, West	33747	–	19	47
Ditto	Mile End Old Tn., East, *Ww*	30017	1	33	75
Ditto	Bow, *ww*L	35067	4	39	141
Ditto	Poplar, *W*	43529	–	52	113
	SOUTH DISTRICTS.				
Lamb. & Southk.	Christchurch Southwark *W*	17069	–	–	1
Southwark	St. Saviour, Southwark, H	19101	–	–	–
Ditto	St. Olave, Southwark, H	7663	–	2	1
Ditto	St. John, Horsleydown, *W*	11393	–	–	–
Ditto	St. James, Bermondsey	25154	1	1	2
Ditto	St. Mary Magdalen, *W*	14505	–	–	–
Southk. & Lamb.	Leather Market	15696	–	–	–
Ditto	Kent Road	18652	–	1	–
Ditto	Borough Road, *W*	15668	–	–	1
Lamb. & Southk.	London Road, L	15490	–	1	1
Southk. & Lamb.	Trinity, Newington	22675	–	1	–
Ditto	St. Peter, Walworth, *W*	14163	–	1	–
Lamb. & Southk.	St. Mary, Newington, H	15082	–	–	–
Ditto	Waterloo Road 1st	15269	–	1	–
Ditto	Waterloo Road 2nd	18640	–	–	1
Ditto	Lambeth Church 1st	19839	–	–	1
Ditto	Lambeth Church 2nd, *W*	25742	1	1	3
Southk. & Lamb.	Kennington 1st	30785	–	1	1
Ditto	Kennington 2nd	20410	–	–	–
Lamb. & Southk.	Brixton	20057	–	–	1
Lamb. & Wells	Norwood, *W*	7402	–	–	–
Southk. & Wells	Clapham	20894	–	–	–
Ditto	Battersea, *Ww*	16600	–	–	3
Ditto	Wandsworth, L	19246	–	–	–
Ditto	Putney	6481	–	–	–
Lamb. & Wells	Streatham	10082	–	–	–
Wells	Dulwich	1723	–	–	–
Southk. & Lamb.	Camberwell, *W* LL	21295	1	3	2
Sk. La. K. & Wells	Peckham	28135	–	–	4
Lamb. & Southk.	St. George, Camberwell	20033	–	4	3
Sk. K. & Wells	Rotherhithe, *W*	24502	–	–	4
Kent	St. Paul, Deptford	37834	–	1	4
Ditto	St. Nicholas, Deptford	8139	–	1	1
Ditto	Greenwich West, H	21696	–	1	1
Ditto	Greenwich East, *W* H	18306	–	–	4
Ditto	Woolwich Dockyard, H	22949	–	–	–
Ditto	Woolwich Arsenal, H	18776	–	–	–
Ditto	Plumstead and Charlton	32974	–	–	–
Kent & Wells	Eltham	3009	–	–	–
Kent	Lee	11807	–	–	–
Wells	Lewisham Village, *W*	7372	–	–	–
Lambeth	Sydenham	10595	–	–	–

NOTE.—The letters placed against the names of the sub-districts denote public institutions situated therein, namely,

W—Workhouse;
H—Hospital;
L—Lunatic asylum;
w—a workhouse not belonging to the district in which it is situated.

The following are Outlying Workhouses:

St. Geo. Hanover Sq. Workh. is in Chelsea North-west sub-dist., 2: 2.
The Strand " " Tottenham-court sub-district, 9: 2.
West London " " Islington East., 10: 2.
East London " " Hackney sub-district, 11: 4.
St. Luke, Middlesex " " Hoxton New Town sub-dist., 20: 3.
London City " " { Mile End Old Town Eastern sub-dist. 24 b: 2, and Bow sub-dist. 25: 1.
Stepney " " Bow sub-district, 25: 1.

You will see there the number of deaths in each sub-district in London of which there are 135. You will also see that the districts in the west of London, the north of London, and so on, suffered very little, whilst in every sub-district supplied by the water of this one company from the Old Ford reservoir the mortality was such as you see in the table. I went to the registrar in Bow and on requesting him to take me to some of the worst courts in the district, he said that the mortality was not confined to those courts, but that it was all over his district, that everybody more or less had diarrhœa, and that in every part of the district there were deaths from cholera. That is one of the characteristics of the epidemic when cholera poison is distributed not by contact but through the water.

2867. As far as you are able to judge, the spread of this epidemic was co-extensive with the supply of this particular water?—It was. But I should mention that the description of the supply of the East London Company is not accurate in one or two points which I will briefly explain. It was written on the evening immediately after this visit, from the best information that we possessed at the time, but of course we knew nothing of what the supply of the East London Company was, except from such publications as we had at our disposal. The statement which was made on the Wednesday attracted the attention of the Queen, of the Lord Mayor of London, and a great number of scientific and benevolent people. The Bishop of London among others, organized a system of relief, and at the same time we set to work and the Registrar-General requested Dr. Frankland to go down and determine exactly the state of the water of the East London Company; Mr. Greaves the engineer of the company came up to the office and complained that this description in the weekly report contained a misstatement as to the supply of water. I immediately showed him the source of our information, and said that if there was anything erroneous we should be very glad to put it right, that we did not at all wish to say anything disparaging of the company. He thereupon said he would write a letter, but instead of writing to the Registrar-General he wrote to the "Times," and in that letter he said that the East London Company had never for some years supplied any but filtered water from their covered reservoir. Mr. Greaves has since admitted that they did supply, as you will see, water occasionally from those open reservoirs of from seven to nine acres which are very near the covered reservoir, and that when they were in certain straits just before the cholera epidemic broke out they did get their water from those open reservoirs.

2868. Do you remember the condition of the several districts in 1849 with regard to cholera?—Yes.

2869. Do you remember what was called the cholera map, the black map, on which the places most afflicted with cholera were marked black?—Yes, we made that map.

2870. And that the cholera was most rife in those districts on the southern side of the river which were called the tide-locked districts, where the sewage arrangements were imperfect, and were the sewage was pounded back and the basements of the houses became saturated with sewage matter?—Yes, it was certainly most fatal in those districts.

2871. Since that the main drainage has been carried out in those districts and the recent epedemic did not visit it with anything like severity as compared with the years 1849 and 1854?—No; that is a remarkable and as we considered a decisive proof of the influence of the water, and it was referred to by us frequently in the weekly returns. The two companies which Mr. Simon has just mentioned, the Lambeth and the Southwark Companies, formerly supplied the south of London with water taken from Battersea and from Hungerford Bridge. In 1849 the whole of the districts of South London suffered to an enormous extent, and nearly equally in the districts supplied by the two companies. In 1849, in the cholera report, I called particular attention to the bad state of the water.

2872. Apart from the water question, was not the condition of the district at that time, from the want of drainage, most of which was under tidal influence and the basements of the houses being constantly kept saturated with filthy matter, a very exciting cause to generate and keep alive the cholera in those districts?—Yes; all the impurities that were thrown into the district were kept there and were not carried away.

2873. Apart from that district which was so heavily afflicted in the east of London, do you attribute the general freedom from cholera of the other parts of the metropolis to the drainage works as well as to the improved water supply?—Yes, drainage is an essential part of any sanitary system.

2874. Are you aware that the district which you have described in the east is just that part of the district where the main drainage is not complete?—Part of it is, not the whole of it.

2875. I mean that there is no outlet until the sewer along the Thames embankment is completed?—Part of it is so.

2876. (*Sir B. Phillips.*) Am I to understand you to say that in those districts where the cholera prevailed very largely the principal cause was the impure water?—I conceive that the cause of cholera existed here, and that the elements of disease from cholera patients were distributed all round London. Cases occurred in every part of London, but in the other districts the mortality was inconsiderable. For instance, in all the districts supplied by the Grand Junction, the West Middlesex, and the Chelsea Water Companies, the mortality was about 3 in 10,000, in those supplied by the Southwark and Lambeth Companies which were formerly so heavily visited, it was about 6 in 10,000, and in those supplied by the New River Company about 8 in 10,000, but in those supplied by the East London Company from the Old Ford reservoirs it was 79 in 10,000. I do not ascribe the whole of that mortality to the water, but I ascribe a large portion of it to the circumstance that the impurity causing cholera was distributed through the water of that company.

2877. Will you be good enough to tell us what you consider those other circumstances to be?—The density of the population also had an influence. We found that where people were packed very closely together they suffered more than where they were distributed more widely over the ground. We have found also that the condition as determined by the annual value of the houses that the people lived in, their poverty had a considerable influence, but not so striking as I should have imagined it would have had. We found also that the elevation of the ground in which the people were living had a very marked influence. In the first report I showed that the mortality on the low banks of the Thames both on the south and on the north side, was from 100 to 150 per 10,000, but as you ascended on successive terraces the mortality was reduced, and at the higher points it came down to 8, so that the elevation of the soil had a considerable influence. That I have been led to suppose since had a good deal of influence upon the purity of the water also. The East London water, for instance, is much worse in the system of pipes in the lower districts than it is in the higher districts. That I have shown in one of the tables which I have put in. Then in 1849, 1854, and 1866, if you take the water of the same company from the same reservoir you will find that the mortality of the people supplied by that water is greater in the low districts than in the high.

2878. (*Col. Harness.*) Where the two sources are equally good?—Yes. I have a tube containing about a hundredth part of cholera matter, which looks like a milky sort of substance; and I should mention that that tube shows the matter in suspension; it is almost clear at the top and it gets a little thicker and assumes a pearly opalescent appearance as

Dr. W. Farr.
May 1867.

you descend. I think that anything like impurity of that sort in suspension in water exists in greater quantities in the lower pipes than it does in the higher pipes.

2879. (*Sir B. Phillips.*) Did it not occur to you that owing to the destitute circumstances of those poor people, and their emaciated condition from want of animal food, many of them also being addicted to gin drinking, when they were attacked by any character of disease they had no strength to resist it?—That was a great cause of the severe mortality.

2880. Do not you think that that had a very material influence upon the mortality, irrespective of the water?—Yes, irrespective of the water it had a very considerable influence, but the same elements existed in contiguous districts supplied with other water without causing this enormous mortality, and it is the enormous mortality which we are endeavouring to account for.

2881. (*Mr. Harrison.*) Was it not the case in particular districts in the visitations of 1849 and 1854 that houses adjoining each other were supplied by two different companies, and did you not find throughout the whole of that district, house by house, that the mortality in the houses supplied by the one company was infinitely greater than where they were supplied by the other company?—Yes, certainly. I should say that the Southwark and Vauxhall Companies were in competition on the south side of the river, and that they often supplied the same street, where the condition of the people was precisely the same in the houses supplied by the two companies. There was so little difference that the people themselves sometimes did not know by what company they were supplied. The Lambeth Company, as you are aware, up to 1852 took its water from the river here, near Hungerford Bridge, I suppose the impurest part of the river probably. In 1849 I recollect going up to Brixton and other places, where there had been two or three deaths in a house. A merchant of London and his wife both died, and when I went to the house I saw the daughter, and on inquiring into some circumstances connected with the case, she brought me some of the water in a tumbler, and it had quite a milky appearance. It had come from the reservoir up at Brixton, and probably contained cholera matter. It contained matter out of the river, at any rate, and we found that the case in a great number of those houses at Brixton which were supplied by the Lambeth Company. After this, as their water was the worst, they were the first to move in the matter, and they went to Parliament and got power in 1852 to go up the river above Teddington. When the epidemic came in 1854 we found that it would be an excellent opportunity for determining the effects of the water, as the two companies supplied the same district, and the houses were nearly of the same class. Dr. Snow, who had started this theory of the distribution of cholera through water came to us, and we gave him every facility for making inquiries, and he went over the houses in the streets supplied by the two companies, and I will just state the result. In 1854 the Southwark Company continued to get its water from Battersea, close to one of the sewers, but the Lambeth Company had gone up to Teddington, beyond the range of the London sewage. In 1849 Bermondsey was supplied by the Southwark Company, and the deaths from cholera were 734, and in the 14 weeks ending the 14th October 1854 they were 829; the number of deaths was greater in 1854 than it had been in 1849. In Lambeth it was found that being supplied by the two companies, and only partly by the Lambeth Company, the deaths in 1849 were 1618, and in 1854 only 904. Then I state in my letter to the Registrar General on the cholera epidemic of 1853–54. "Dr. Snow, who has devoted "much time to the investigation, having procured "from this office the addresses of the persons who died "of cholera in Kennington, and some other sub-"districts, states, as the result of an inquiry from "house to house, where the pipes of the Lambeth "Water Company are intimately mixed with those "of the Southwark Company, that in the seven "weeks ending August 26th, of 600 deaths from "cholera, 475 have happened in houses supplied "by the Southwark Company, 89 in houses sup-"plied by the Lambeth Company, 13 in houses "supplied by pumps, wells, and springs; 8 in "houses which derived their water directly from the "Thames and from ditches. The registrars on the "south side of London were instructed to inquire in all "cases of death by cholera" and into the water supply. In many cases they could not get the information, as the people did not know which company supplied the water, but this was the general result. I should state that the Lambeth Company supplied 26,000 houses, and the Southwark Company 40,000 houses. The deaths from cholera during six weeks in the houses supplied by the Southwark Company were 2,284 in 40,000 houses, while 294 deaths occurred in the houses supplied by the Lambeth Company out of 26,000 houses. The proportions are these, to every 1,000 houses supplied by the Southwark Company there were 57 deaths from cholera, and to every 1,000 houses supplied by the Lambeth Company 11 deaths. We afterwards got a return from the companies of the houses they supplied, and we ascertained the number of deaths in those houses from our books, and the general result was summed up in this way, that in the houses supplied by the Lambeth Company the deaths were 12 per 1,000 in 1848–9, and in 1853–4 only 4 per 1,000. In the case of the houses supplied by the Southwark Company the number of deaths per 1,000 was 12 in 1848–9, and 13 in 1853–4, so that the Lambeth Company had fallen from 12 to 4 while the Southwark Company had got worse. That seemed a decisive and conclusive experiment, showing the influence of the supply of water in a cholera epidemic. It was that which enabled us so decisively to say that the East London districts which were affected in the same way precisely as those in South London had been, must have been affected through the distribution of the poison by the water. We went on with the inquiry week after week, getting all the information on the subject we possibly could, and the conclusion to which we had been lead at the first was fully confirmed. I should say that the very week after Mr Greaves, who grew fully alive to the importance of the subject, came up, the cholera epidemic in the east of London began rapidly to decline whilst it remained stationary in the rest of London. The conclusion we came to was, that the Company had resorted to those open reservoirs which contained dirty water, and distributed it for a certain time more or less in a certain number of days, but then they took such precautions as led gradually to the purification of the water, and the water in the end became as good as that of the other companies, and the mortality declined.

2882. (*Sir. B. Phillips.*) Do they get their water from the same source still?—Yes; the water, until it comes down to the Old Ford reservoir, as far as we could see and learn from its effects upon the population, was as good as that of any other company, but when I went down there the river Lea was full of the sewage of West Ham, which had been poured into that river, and it was going up and down within a very short distance of the reservoirs of the East London Company; the banks were gravel and loose, and of course the impure water from the Lee got into the open reservoirs, and as Captain Tyler has since discovered, got into the covered reservoir.

2883. (*Sir J. Thwaites.*) Has your attention been directed at all to the question of hard or soft water, and their effect upon the human system?—I have often thought it most important to endeavour to determine the effect of hard and soft water on health, but at present I am not satisfied that we are able to state the precise effect of hard and soft water on health. I heard a gentleman here mention that stone had been said to be prevalent in chalk countries, and I know that a paper was written on the subject, and published in the transactions of the Royal Society,

showing that there were more stone cases and cases of lithotomy in Norfolk than in some other counties: but there was no registration of the cause of death at that time; the means of registration were very imperfect, so that I do not feel that we are at present able to say what is the precise effect which lime and other substances of that sort have upon health. I think the subject ought to be investigated.

2884. Do you think there really are more cases of stone in Norfolk than in other counties?—I am not satisfied that the fact is established.

2885. (*Mr. Harrison.*) Your view is generally that those waters in which human excreta enter to any extent are dangerous?—Decidedly.

2886. Do you think that the filtration through earth from applying the sewage to the land as manure would take away all the dangerous effect, or would you consider that after being filtered through the land there would still be a dangerous tendency in the water?—I should not think the danger considerable if it passed through a certain thickness of earth. I should not conceive that the danger would be very great, or indeed any such as need deter us from using the water, but if manure is put on the land it would be washed down in certain cases into the rivers.

2887. That would depend would it not upon the nature of the soil?—Yes.

2888. But with regard to a chalk soil you would have no fear whatever?—Certainly not.

2889. On a clay soil you might find a great deal of the sewage brought off in cases of flood?—Yes.

2890. (*Sir B. Phillips.*) Do you think that if this London water could be free from all its impurities it is a good quality water for consumption?—I confess that when I see that this Loch Katrine only contains in 100,000 grains three grains of impurities of any kind, and that it contains no trace whatever of sewage or anything like sewage, I should have greater confidence in water brought in that way from the hills than I should in water taken from the river; at the same time I am not prepared to say that the water from the river, with great precautions as to letting sewage into it, might not be made a very decent sort of water.

2891. (*Sir J. Thwaites.*) Is your confidence in the hilly districts as a gathering ground, or is it in the condition of the water?—The water would be purer there.

2892. My question had reference to the gathering ground being freer from any vegetable decomposition?—In Scotland and Wales, and other places in the mountainous districts where the rain is perpetually coming down in torrents the water is pure, and it evidently, I should think, is in the best possible state for the supply of our wants, both for drinking purposes and for domestic purposes of every kind.

2893. And it must of necessity be purer than any water from the Thames basin, having regard to the state of cultivation in that area?—Necessarily so; I think more danger lurks in the Thames water. I will just mention the difficulty in keeping out impurities by referring to a little stream which I know, the Ravensbourne: the water of the Kent Company is now the worst water according to Dr. Frankland, but I believe they say that they do not use the Ravensbourne, and if they do they take great precautions in filtering it. But up to the very heads of the streams the people are putting their closets or drains and pouring them into those small streams, and it is almost impossible to prevent them. There is a stream at Bromley, for instance, which I noticed the other day, and there is a watercloset over it in a small cottage where I believe there were several deaths from cholera in 1849: it is almost impossible to prevent the pollution of the heads of such rivers. It will be an immense advantage, no doubt, if those measures are carried out for which an Act has been obtained, so far as keeping out the great town sewers from the Thames is concerned. The evils we suffer from are felt on the Seine. I believe that our water is much purer than the Paris water; there is no doubt about that.

2894. (*Mr. Prestwich.*) You mean the water that they were using in Paris, not the water that they are now using?—The last outbreak of cholera was caused by impure water and they still get water from the Seine.

2895. Are you not aware that they have now made an aqueduct to bring water from the chalk districts?—Yes, a certain portion of it, but it is not so much as one would be led to suppose from the way in which they speak of it. You will see by the report that the larger proportion is taken from the Seine and the Canal de l'Ourq. A gentleman who has written a very good book on the subject has shown that in proportion as the Seine gets low in water the sewage discharged remaining the same, the water of course became impure, and just at the time of the maximum impurity of the Seine water, that explosion of cholera which we remember, took place in Paris.

2896. (*Mr. Harrison.*) Taking the case of Glasgow, the death-rate by this return which you have put in is 31 per 1,000?—Yes.

2897. And the next to that is Newcastle-upon-Tyne, 28 per 1,000?—Yes.

2898. Taking it that both those towns are supplied by a constant service, and that in the case of Glasgow the water is the purest of any supplied in the kingdom, is it not obvious that water forms only one of the elements in the sanitary state of a town?—It is quite clear that it is so, and that is why I say that an investigation is necessary, and I think that you have the means of almost determining the effect of comparatively pure water. I have here a return for 52 weeks of the year 1866, of the mortality in Glasgow and now in London, by which it will be seen that the mortality in Glasgow is 30 on the average, and it was high before they got this water from Loch Katrine, and the mortality in London was 26.

2899. (*Sir J. Thwaites.*) There you have the contrast still greater, as they have a purer water in Glasgow than we have?—Yes.

2900. (*Col. Harness.*) Have you made a comparison of Glasgow before and after the introduction of the Loch Katrine water?—No. This subject of the influence of pure water and of soft and hard water requires investigation, and the Commission has the means of carrying out that investigation.

2901. You stated that there are some data to begin with, have you classified them?—No, not so as to satisfy my own mind. In the case of Glasgow you would think that all the people of Glasgow got this water—soft water—but I believe they do not.

2902. (*Mr. Harrison.*) Now they do, do they not?—Yes, in taps at the bottom of the houses, and so on, but it is not distributed over the houses, so as to have the same effect as it has in other districts.

2903. (*Sir J. Thwaites.*) They have merely standcocks in courts?—Yes, and it is necessary to go into all those details before you can say whether the town is thoroughly supplied with pure water, or not; it is brought there, but whether it is distributed so as to produce all its beneficial effect is another question.

2904. (*Col. Harness.*) But Glasgow receives no other water, does it?—No other water is now used on the north side of the Clyde. On the south side, Dr. Gairdner informs me that "Gobals gravitation water" is still in use.

2905. (*Mr. Harrison*). They have the largest supply of water per head, have they not, of any in the kingdom, amounting almost to 50 gallons per diem?—Yes. Dr. Gairdner, the health officer of Glasgow, I should think would be prepared to tell this Commission what has been done in supplying every house in Glasgow with water, and also to trace its effect; and, in Manchester, you would also have an opportunity of showing the effect of pure water without a proper system of sewage. As Sir John Thwaites very properly noticed it is necessary that the two should be combined in order to get the maximum effect.

2906. (*Sir J. Thwaites.*) In Glasgow the condition of the river, and the great want of drainage in the town had to be taken into account, and that might

have aggravated the epidemic?—Yes, and no doubt the crowding of the population must have had another bad effect.

2907. (*Mr. Harrison.*) And possibly the whiskey being cheap had a bad effect in many cases?—No doubt that had its effect, but I constantly see those partial efforts of reforms: even in the metropolis where we have such a capital system of sewage to a certain extent, the full advantage of that, as we have often noticed, is not felt because those sewers are not in communication with every house, as they ought to be.

2908. (*Sir J. Thwaites.*) That is becoming very rapidly accomplished, is it not?—Yes. I think of investigating the matter scientifically in order to see what the effect of the system of sewage is, for instance, when it is properly carried out to every house so as to produce its maximum effect. And also with regard to the water supply, if you carry your pure water to every house, and let people have an adequate supply of it you ought to experience its full effect; but you will never experience its full effect till you join with it a system of sewage such as you have in the south of London. And you have got an enormous difference which I should like to mention where you have the two combined, that is to say, the drainage and the water supply. I will read this extract from the Registrar-General's weekly table for December 8th, 1866, at the end of the epidemic: "A "most gratifying and conclusive proof of the good "effects of improved water supply is afforded by the "experience of the South London districts which "were undrained, and were supplied with the foul "sewage water of the Thames by the Southwark "and Lambeth Companies in 1849." There you had the maximum of evil—you had bad water and no drains. Then the mortality by cholera in 10,000 inhabitants was 120. I believe that the drainage of South London was not carried out in 1854. There were great improvements in the local drainage, but not in the outfall. Then the mortality when the purer water was supplied by the Lambeth Company fell from 120 in 1849 to 87 in 1854, and in 1866 it was reduced to 8 in 10,000. From cholera and diarrhœa the deaths out of the same numbers living in that district, with the maximum effect of bad water and imperfect drainage, were 142, in the intermediate period 104, and in the last period 15. As the water improved and the drainage the deaths declined to this marvellous extent. Similar if less striking evidence of the effects of pure and impure waters is supplied by the experience of the other London companies.

2909. (*Col. Harness.*) Did you receive the same detailed information of the deaths and the cause of death from Glasgow that you did in London?—The Registrar-General of Scotland does now.

2910. Did he before the Loch Katrine water was introduced?—He did not; but they had a local system of returns—a very valuable one, indeed—one of the first in the kingdom; and they had the means of comparing the rate of mortality.

2911. They had the means of comparing what the state of disease was, all other things being the same?—Yes.

2912. (*Sir J. Thwaites.*) Have you not that return in your office?—No. The Registrar-General for England only receives the returns for England.

2913. The Scotch returns are published, are they not?—Yes.

2914. You have a printed copy of them, have you not, at the office?—Not for the exact municipal boundary of Glasgow.

2915. Could you put it in your evidence, so as to give what Colonel Harness suggests, namely, the contrast between the mortality in Glasgow prior to the supply of the Loch Katrine water and since?—If you will allow me I will write to the Health Office at Glasgow, Dr. Gairdner, or the Commission might write, and ask him to send the information up to you; I will do all I can to supply the information that the Commission desires.

2916. (*Mr. Prestwich.*) Could you not furnish the Commission with returns from towns which have been supplied with soft water within a late period, such as Manchester and Newcastle, showing the same comparison?—We could supply the information as to diseases and mortality.

2917. (*Sir J. Thwaites.*) Take Hull for example, could you give us the result there?—At Hull the result is very decisive, we have had no cholera at all of any account in the recent epidemic of last year. The deaths from cholera in the districts of Hull and Sculcoates in the three epidemic years 1849, 1854, and 1866, were 1,834, 27, 21.

2918. (*Mr. Harrison.*) Ought not such a return to contain the quantity consumed per head before and after the change in the supply?—Yes, and the distribution; I think you ought to get that from the towns to make it of any use.

2919. (*Sir J. Thwaites.*) However, you can give the Commission the fact that in the year 1854 the mortality in certain towns was so many in each 1,000 of the inhabitants, and that since the supply of water of certain quality the mortality has increased or decreased?—Yes.

2920. And also its influence on the several diseases?—Yes, as far as I can find it out. It is necessary that I should know in what years the supply was changed.

2921. Will you take a reasonable number of years before the supply was changed and after so as to give the result of a fair average?—Yes.

2922. (*Mr. Prestwich.*) How far back do your returns go?—To the year 1837.

2923. (*Mr. Harrison.*) Such an investigation as you suggest of the whole question is necessarily one of a scientific character of the utmost nicety?—Yes.

2924. And also one that would require considerable time?—Yes.

2925. Do you think it possible that this Commission could make that inquiry sufficiently satisfactory, or are they a sufficiently scientific body to make it. Is not that more an investigation for a commission of medical men?—I think not for medical men only. The course which we have pursued generally on commissions with which I have been connected has been to appoint some one to conduct special inquiries for us. In the commission on the sanitary condition of the Indian army we employed people to conduct those inquiries and to devote their time to them. The Commissioners of course could not devote the whole of their time to them.

2926. The view which you present in your letter to the Commission is that some of the effects of water are immediate and easily perceptible; others are slow and are some time before they take effect; and finally, others are only felt as they operate on the young and on successive generations?—Yes.

2927. That is an extent of inquiry which it is quite obvious that this Commission could not arrive at any satisfactory conclusion upon?—They would employ proper persons to do it for them. The effect of bad water on children of different ages is very different. I believe that the worms which afflict children in certain towns enter them through the impure water.

2928. A change of water, as is well known, has an effect upon people. For instance, on changing from a soft water to a hard water, going into a limestone district where the water comes from the magnesium limestone, many people are made ill for a time?—Yes, and that has an effect on animals also no doubt. I remember going over John Day's training establishment at a time when he had some hundred horses training. His establishment was situated on the chalk where the water was hard, and when I asked him about the water that the horses drink he said that he gave them nothing but rain water, that they would not drink the hard water, and he found that a perfectly pure water suited the horses best. I do not know what other trainers do. The character of the water no doubt has a great influence on the strength and health and vigour of man, and I do not think that

we have yet determined the precise effect of hard water on the human constitution.

2929. (*Mr. Harrison.*) As far as your experience goes, are we to take it that this view which is conveyed in the report of Dr. Frankland is one that you concur in, namely, that at the present moment taking his analysis there is nothing that is really bad in the water supplied to London?—Not on that particular day. I should qualify it myself always in that way. I can conceive that the character of the water varies from day to day; it varies with the temperature and with the rainfall, and with a variety of circumstances. All we know is that from the analysis which Dr. Frankland has hitherto made he has come to the conclusion that the water supplied to London has contained something very noxious, but that it did not contain anything noxious at the time that he took it at the mains. Professor Abel at Woolwich tells me that he finds an essential difference in the chemical character of the water pumped from the chalk at different states of the tide in the Thames, showing that there is a communication in some way or other through the chalk into the wells which are in proximity to the Thames.

Dr. W. Farr.
8 May 1867.

2930. (*Col. Harness.*) So that water affected by the Thames as it passes through that country may be affecting the water drawn from the chalk wells?—It might do so.

The witness withdrew.

Adjourned to to-morrow at 11 o'clock.

Thursday, 9th May 1867.

PRESENT:

SIR JOHN THWAITES IN THE CHAIR.

Colonel HARNESS.	THOMAS ELLIOT HARRISON, Esq.
Alderman Sir BENJAMIN PHILLIPS.	JOSEPH PRESTWICH, Esq.

JOHN THORNHILL HARRISON, Esq., examined.

J. T. Harrison, Esq.
9 May 1867.

2931. (*Chairman.*) You are a civil engineer, are you not?—I am.

2932. And you are one of Her Majesty's Commissioners on the pollution of rivers?—I am.

2933. You have made your report have you not?—We have made reports upon the Thames and of the Lea.

2934. Have those reports been published?—They are both published. The report upon the Lea has been presented to Parliament, and I suppose will soon be distributed; I can lay a proof copy of that report before the Commission (*handing in the same*).

2935. You have had your attention directed, have you not, to the water supply of the metropolis, especially from the Thames basin?—We have. That subject was referred to our Commission in part in consequence of a letter written by Mr. Neate, the member for Oxford, which you will see at the commencement of our reports.

2936. Your attention then was directed to the necessity for purifying the river and intercepting all the sewage and other polluting matter which finds its way at present into the river, and you have reported as to the means of interception?—Yes, we have done so; that is the primary object of our Commission; the water supply is a secondary object to be carried out so as not to interfere with the first object, namely, that of remedying the pollution.

2937. Then the water supply was a secondary object with your Commission?—Yes.

2938. But you did, I suppose, examine that question in connexion with the purification of rivers?—Yes, and in consequence of instructions from Sir George Grey, whenever we had an opportunity of gaining information during our inquiry we took the evidence that was tendered to us.

2939. You have done so agreeably to the letter dated Whitehall, July 7th, 1865, signed H. Waddington, giving your Commission additional instructions with reference to that subject?—Exactly so.

2940. In connexion with the water supply, has your attention been directed to the capacity of the Thames basin to yield a sufficient supply of water for the metropolis?—Yes, during our inquiry we received a considerable amount of information upon the subject, this I have endeavoured to put together, so that we (the Rivers Pollution Commissioners) might draw conclusions for our future report upon the subject of water supply.

2941. Have you tabulated the information which you obtained for the purposes of your Commission?—Yes.

2942. And I suppose you are prepared to hand in a copy of those tables for the use of this Commission?—Yes.

2943. Your attention was necessarily directed to the rainfall in the district?—It was so.

2944. Can you state to this Commission what steps were taken by you or the data upon which your calculations were made with respect to the rainfall in the area of the Thames?—Mr. James Simpson, who is Engineer of the Chelsea and Lambeth Waterworks Companies, offered during the inquiry, and subsequently sent in a return of the daily rainfall at Kingston-upon-Thames for 11 years, from 1855 to 1866.

2945. That was taken, I presume, at the waterworks?—Yes, near the waterworks, and I subsequently, (not during our inquiry,) in conversation with Mr. Brown, of Cirencester, found that he (Mr. Brown) had, during the same period, kept an accurate daily record of rainfall at Cirencester throughout the same 11 years, and he very kindly sent me these observations for the use of the Rivers Commission.

2946. That would refer, would it not, to the upper part of the Thames?—Yes.

2947. Have you had any information as to the other parts of the basin?—We obtained information from other parts, but from no source giving the daily rainfall as obtained in those two instances.

2948. Not with anything like regularity?—No.

2949. You had not reliable data?—I have not.

2950. Then the two gauges which you refer to would appear to represent the two extremes of the valley, that is to say, the lowest point and probably highest?—Not quite the highest, but it would be a fair average of the upper part of the basin. I thought that the two records would represent fairly an average rainfall of the whole Thames basin.

2951. Can you give us the result of those two gaugings?—I will lay before the Commission Table No. 1.

The witness delivered in the following table:

W. T. Harrison, Esq.

9 May 1867.

No. 1.—Table showing approximately the Monthly Average Rainfall, in Inches, on the Thames Basin in each Month, from April 1855 to April 1866.

Year.	April.	May.	June.	July.	August.	September.	Totals.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1855 -	0·455	1·905	1·615	5·615	1·660	1·715	13·06
1856 -	2·975	3·835	1·255	1·250	3·725	3·050	16·09
1857 -	2·100	1·175	2·660	2·190	2·150	2·915	13·19
1858 -	4·360	2·495	2·240	2·430	1·875	2·020	15·42
1859 -	2·410	1·830	2·850	2·095	2·080	3·660	14·92
1860 -	1·160	3·305	5·820	1·755	4·390	3·285	19·71
1861 -	0·875	2·240	2·640	3·275	1·925	1·295	11·25
1862 -	2·380	4·025	2·690	1·930	2·850	3·120	17·00
1863 -	0·935	1·290	4·910	0·725	2·875	3·750	14·47
1864 -	1·230	1·775	1·375	0·610	1·420	2·145	8·55
1865 -	0·960	2·740	2·795	4·150	3·940	0·215	14·80
	19·840	26·610	30·85	26·020	28·890	27·170	158·46
Average	(1·800)	(2·420)	(2·800)	(2·360)	(2·620)	(2·470)	(14·40)

Year.	October	November.	December.	January.	February.	March.	Totals.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1855-6 -	5·625	1·105	1·300	2·645	1·545	1·130	13·35
1856-7 -	2·785	1·020	2·505	2·895	0·840	1·545	11·59
1857-8 -	4·225	1·300	0·740	0·740	1·455	1·115	9·57
1858-9 -	1·650	0·675	2·260	1·115	1·720	1·765	9·18
1859-60	2·740	2·645	2·585	3·425	1·130	2·135	14·66
1860-1 -	1·850	2·680	2·610	0·910	2·325	2·585	12·96
1861-2 -	1·275	4·615	1·595	2·315	0·455	4·480	14·73
1862-3 -	4·395	0·755	1·900	3·150	0·570	0·925	11·70
1863-4 -	2·940	2·010	1·565	1·355	1·485	3·115	12·47
1864-5 -	1·930	3·155	1·290	4·085	2·270	1·160	13·89
1865-6 -	6·455	3·220	1·990	3·930	4·455	1·570	21·62
	35·870	23·190	20·340	26·560	18·270	21·520	145·72
Average	3·260	2·110	1·850	2·410	1·660	1·960	13·24

Total rainfall in 11 years was 304·18, averaging 27·65 inches per annum.
February, on the average, is the driest month; October decidedly the wettest; the order being February, April, December, March, November, July, January, May, September, August, June, and October.

Note.—This rainfall is calculated from an average of the records kept by James Simpson, Esq., C.E., at Kingston-on-Thames, and by Thomas Brown, Esq., at Cirencester.

2952. (*Mr. Harrison.*) Will you explain the nature of this table?—This table (No. 1.) gives approximately the average rainfall of each month during 11 years upon the Thames basin.

2953. That is embodied, is it not, in two periods of the year?—Yes, one period, the summer months from April to September inclusive, and the other from October to March, inclusive. The result of the addition of those, and averaging them over the 11 years, shows that the month of October is decidedly the wettest month of the year, the rainfall being considerably higher than in any of the other months. It shows also that February is the driest month.

2954. And the average rainfall of these years is what?—27·65 inches per annum. The rainfall at Cirencester is about four inches more than the average at Kingston, but there were one-half more days upon which rain was recorded at Kingston than there were at Cirencester. This is easily accounted for, as the heaviest rain comes from the west, and Cirencester being about 360 feet above Ordnance datum and much to the westward of Kingston, receives the larger rainfall, but Kingston, from its position, receives showers both from the east and west.

2955. (*Chairman.*) Is there anything at the point where the upper gauge is fixed to deprive it of the advantage of those eastern showers?—I take it that the eastern showers do not reach so far; the western rainfall is much heavier.

2956. Then it becomes exhausted before it arrives at Kingston?—Partly so.

2957. (*Mr. Harrison.*) The general result of this table is to show that in the months from April to September the average rainfall is 14·40 inches, and from October to March 13·24?—Yes.

2958. The two together making 27·65 as the average rainfall over the whole of the 11 years?—Yes; I think before going to Table No. 2, it would be well if I were to put in another, which I will call No. 1A.

The witness delivered in the following table:

No. 1A.

Table showing the Rainfall, Percolation, and Evaporation, in Inches, during the Years 1861 to 1865, inclusive, at King's Langley, as recorded by John Evans, Esq., and at Lea Bridge, as recorded by Charles Greaves, Esq., C.E.

Date.	Rainfall.				Percolation.				Evaporation.			
	King's Langley.		Lea Bridge.		King's Langley.		Lea Bridge.		King's Langley.		Lea Bridge.	
1861	Inches.	Total Inches.	Inches.	Total Inches.	Inches.	Total Inches.	Inches.	Total Inches.	Inches.	Total Inches.	Inches.	Total Inches.
Quarter to March -	4·81		6·932		3·38		3·062		1·43		3·870	
„ June -	4·16		4·141		—		0·183		4·16		3·953	
„ Sept. -	6·22		5·374		1·13		—		5·09		5·374	
„ Dec. -	6·01		7·852		3·00		2·762		3·01		5·090	
		21·20		24·299		7·51		6·012		13·69		18·287
1862												
„ March -	6·62		6·645		5·19		3·437		1·43		3·208	
„ June -	7·90		7·813		1·77		1·649		6·13		6·164	
„ Sept. -	6·47		5·332		—		—		6·47		5·332	
„ Dec. -	6·45		6·791		2·53		3·462		3·92		3·329	
		27·44		26·581		9·49		8·548		17·95		18·033
1863												
„ March -	4·56		4·062		2·97		2·387		1·59		1·675	
„ June -	6·16		5·270		0·19		—		5·97		5·270	
„ Sept. -	7·24		5·206		—		—		7·24		5·206	
„ Dec. -	4·80		5·228		2·63		1·374		2·17		3·854	
		22·76		19·766		5·79		3·761		16·97		16·005
1864												
„ March -	4·44		4·728		3·26		2·862		1·18		1·866	
„ June -	4·45		3·770		0·45		0·062		4·00		3·708	
„ Sept. -	3·97		3·936		—		—		3·97		3·936	
„ Dec. -	4·10		3·457		—		0·899		4·10		2·558	
		16·96		15·891		3·71		3·823		13·25		12·068
1865												
„ March -	6·83		7·145		3·55		5·425		3·28		1·720	
„ June -	4·97		5·083		—		0·026		4·97		5·057	
„ Sept. -	7·63		7·896		—		0·837		7·63		7·059	
„ Dec. -	10·82		9·124		4·37		4·862		6·45		4·262	
		30·25		29·248		7·92		11·150		22·33		18·098
Totals in 5 years -	- -	118·61	- -	115·785	- -	34·42	- -	33·294	- -	84·19	- -	82·492
Average of 5 years -	- -	23·72	- -	23·150	- -	6·88	- -	6·660	- -	16·84	- -	16·490

Average percolation at King's Langley, 29 per cent.; average evaporation 71 per cent.
„ „ Lea Bridge 28·8 „ „ „ 71·2 „

Note.—According to Mr. Beardmore's observations the proportion of the rainfall which actually flowed into the river from the Lea Basin in the years 1851, 1852, 1856, and 1858 was on an average only 18·5 per cent.

2959. (*Chairman.*) Will you be good enough to describe that Table No. 1A?—In addition to the daily record of rainfall at Kingston and Cirencester from Mr. Simpson and Mr. Brown, Mr. Evans kindly gave me the monthly record of percolation at King's Langley, which I have made use of in the subsequent tables; but during our inquiry on the Lea, Mr. Greaves, who is the Engineer of the East London Waterworks, gave us his observations on percolation for several years. This table (No. 1A.) has side by side the observations of Mr. Greaves and of Mr. Evans, and you will observe that the results strikingly accord. The average rainfall at King's Langley during five years was 23·72 inches, and the average rainfall at Lea Bridge 23·15 inches. That was for the five years from 1861 to 1865 inclusive. The percolation observed by Mr. Evans at King's Langley was 6·88 inches, and the percolation at Lea Bridge as reported by Mr. Greaves was 6·66 inches,—the difference between the rainfall and percolation they give as evaporation—that at King's Langley being 16·84 inches, and that at Lea Bridge 16·49 inches.

2960. How do they arrive at the absorption or percolation as you call it?—The Dalton gauge used by Mr. John Evans is a cylinder 18 inches in diameter, turned to a knife edge at the top and sunk to a depth of three feet below the level of the ground, filled with fragmentary chalk and covered with grass similar to the surrounding ground. The rain which passes through is collected in a gauge and measured from time to time, the rainfall on the surface at the same time being recorded.

2961. I presume they take the quantity measured at the bottom of the trench as that which is absorbed and all plus that they give as evaporated?—Yes evaporated or taken up by vegetation. The average percolation at King's Langley for the five years is 29 per cent. and the evaporation 71 per cent. The average percolation at Lea Bridge is 28·8 per cent. and the evaporation 71·2 per cent.

2962. If I rightly understand the object of this test, it is to ascertain the absorbing power of the land in that area and the amount of evaporation, in order to ascertain what would really be available as a water supply?—Quite so.

2963. Can you give us, in figures, the net result that would be available for a water supply, or that finds its way into the rivers?—Yes, that will come in subsequently. I may mention here that the object of Mr. Evans and his predecessor Mr. Dickenson was to ascertain what quantity of water they could rely upon during summer seasons for working their water-wheels, they being large paper manufacturers at King's Langley, and those observations were made with that object. The greater number of the observations I have used are reported in the transactions of the Institution of Civil Engineers; the additional observations complete the table up to April 1866.

2964. You have no doubt, have you, that those investigations have been conducted with intelligence and fair accuracy?—I believe so, the object of the parties conducting them being to arrive at the truth.

2965. As far as you are able to judge from the returns made, those gentlemen appear to understand the subject?—Yes, the subject has been frequently discussed at the Institution of Civil Engineers, and I believe the records are reliable.

2966. (*Mr. Harrison.*) I see a note appended to this table (No. 1A) which is to this effect: "According "to Mr. Beardmore's observations, the proportion of "the rainfall which actually flowed into the river "from the Lea basin in the years 1851 and 1852, "1856 and 1858, was, on an average, only 18·5 per "cent." ?—Yes. You will observe that those are special years, they do not refer to the years mentioned here, and therefore I put that down as a note. Mr. Beardmore gave it in evidence before the Rivers Commission on the Lea inquiry. I will now hand in Table No. 2.

The witness delivered in the following table:—

No. 2.

TABLE showing approximately the RAINFALL on the THAMES BASIN, the DISCHARGE by the THAMES at KINGSTON, the EVAPORATION and the ADDITION to or SUBTRACTION from the SUBTERRANEAN RESERVOIRS in Inches over the entire Surface, half-yearly and yearly, from April 1855 to April 1866.

Date.	Rainfall.		Discharge at Kingston.		Evaporation.		Volume added to or drawn from Subterranean Reservoirs.			
							Half-yearly.		Yearly.	
	Half-yearly.	Yearly.	Half-yearly.	Yearly.	Half-yearly.	Yearly.	+	−	+	−
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1855–6 April to September	13·06	26·41	2·225	8·90	10·36	15·77	0·475	—	1·74	—
1855–6 October to March	13·35		6·675		5·41		1·265	—		
1856–7 April to September	16·09	27·68	3·585	9·57	11·77	17·94	0·735	—	0·17	—
1856–7 October to March	11·59		5·985		6·17		—	0·565		
1857–8 April to September	13·19	22·76	3·195	7·54	12·79	18·84	—	2·795	—	3·62
1857–8 October to March	9·57		4·345		6·05		—	0·825		
1858–9 April to September	15·42	24·60	2·635	5·49	11·43	19·78	1·355	—	—	0·67
1858–9 October to March	9·18		2·865		8·35		—	2·025		
1859–60 April to September	14·92	29·58	2·285	9·23	14·09	19·54	—	1·455	0·81	—
1859–60 October to March	14·66		6·945		5·45		2·265	—		
1860–1 April to September	19·71	32·67	6·705	15·89	11·46	16·87	1·545	—	—	0·09
1860–1 October to March	12·96		9·185		5·41		—	1·635		
1861–2 April to September	11·25	25·98	3·235	9·07	9·36	15·20	—	1·345	1·71	—
1861–2 October to March	14·73		5·835		5·84		3·055	—		
1862–3 April to September	17·00	28·70	6·135	11·21	12·60	19·51	—	1·735	—	2·02
1862–3 October to March	11·70		5·075		6·91		—	0·285		
1863–4 April to September	14·47	26·94	2·555	7·04	13·21	18·16	—	1·295	1·74	—
1863–4 October to March	12·47		4·485		4·95		3·035	—		
1864–5 April to September	9·55	23·44	2·765	6·84	7·97	16·75	—	1·185	—	0·15
1864–5 October to March	13·89		4·075		8·78		1·035	—		
1865–6 April to September	14·80	36·42	2·375	11·00	12·60	22·00	—	0·175	3·42	—
1865–6 October to March	21·62		8·625		9·40		3·595	—		
	305·18		101·780		200·36		18·360	15·320		
		305·18		101·78		200·36				
Yearly average		27·74		9·25		17·30			9·59	6·55

One inch of rain over the Thames Basin (area 102,480,000,000 square feet) gives 53,375,000,000 gallons of water.

NOTE.—The rainfall is calculated from the average of the records kept by James Simpson, Esq., C.E., at Kingston, and Thomas Brown, Esq., at Cirencester.

The discharge is calculated from data supplied to the Rivers Commission by James Simpson, Esq., C.E.

The evaporation is calculated from observations on percolation by John Evans, Esq., of King's Langley, with an addition for extra evaporation from the clay in winter.

J. T. Harrison, Esq.

9 May 1867.

2967. (*Chairman.*) Will you explain Table No. 2?—In Table No. 2 the rainfall in inches is given half-yearly, and also yearly in the first two columns. In the third and fourth columns is given the discharge at Kingston. I should explain to the Commission that, during our inquiry on the Thames, Mr. Simpson stated to us that he had made observations daily at 9 o'clock in the morning since 1855 as to the height of the water in the Thames above the point where the Metropolitan water companies take their supply near Kingston.

2968. Had he a careful section of the river at that point?—Yes, and with the permission of the Commission I will put it in (*handing in the same. See Appendices A, B, 1 and 2*). He gave to us this longitudinal section of the Thames, and these cross sections at the point where the observations were made.

2969. Near to their works, I presume?—Yes, above their works; some miles above Teddington Lock.

2970. There would be no difficulty in calculating the exact quantity that passed that point marked, having a careful section of the river?—I would not say that it was exact, but I am sure that the result is approximately true. His observations are exact for every day during the 11 years from 1855 to 1866.

2971. Can you give us the result of those observations?—Mr. Simpson gave us some observations as to the velocity of the water when the river was at certain heights. From Mr. Beardmore's tables I calculated what the volume of water passing daily would be when the river was at different heights, and from the volume so calculated I have made this diagram No. 1 which shows the daily flow of water past Kingston during those 11 years (*describing the diagram to the Commission*).

2972. (*Mr. Harrison.*) Would the red line divided into days give the actual flow in gallons at that point for every day for the 11 years?—Yes, if you draw a perpendicular line at any date from this base, the height from the base line to the point where the perpendicular line cuts the section, shows the volume of water passing down the river Thames that day. The blue is the average daily rainfall during each month.

2973. What does the blue represent?—The blue represents the actual volume of water that fell upon the whole of the Thames basin during each month.

2974. (*Col. Harness.*) Therefore it was a flood at that point?—It might or might not be a flood the whole way up.

2975. How do you explain it, that here we have got a flow greater than the rainfall?—I think I can explain it to you.

2976. (*Chairman.*) This diagram represents the flow in all cases at Kingston?—Yes, every day.

2977. (*Col. Harness.*) But this (*pointing to the diagram*) is taken, is it not, from the whole basin above Kingston?—The date of that flow is about the middle of February 1856. Those little marks at the bottom of the diagram represent in parts of an inch the daily rainfall. The brown at Cirencester, and the red at Kingston. They show that the flood was chiefly from Cirencester, as there was comparatively little rain at Kingston, but heavy rain was falling in the middle of February, when the ground was saturated, and probably the greater part of the water that fell on the surface flowed off.

2978. (*Mr. Harrison.*) In order to arrive at that you must go back, must you not, even for weeks before?—Yes.

2979. (*Col. Harness.*) Is not this owing to the arrangement of the two scales, the two scales do not show the relative proportion?—They do not show the relative proportion of the rainfall and discharge each day.

2980. If we forget the red and look at the blue we have the relative quantity of the red, and if we look at the red and forget the blue we have the relative quantity of the blue, the two will not lie one upon the other?—Quite so. But this was the only way in which I could show the average; it sometimes may happen that there is a larger discharge than the rainfall would show for the particular time. For instance, when there is a copious discharge from the springs, a comparatively small rainfall raises the river, producing almost a flood. When the springs are very low, and the ground very dry, as was the case in September 1865, there may be very heavy rainfall, showing hardly any flood, the water being evaporated or absorbed by the land.

2981. (*Chairman.*) That is dependent upon the absorbing power of the ground?—Yes.

2982. When the ground is saturated of course the quantity of rain that falls must necessarily run off?—Yes. You will observe that in September 1865 there was hardly any rainfall and the river was extremely low, and the ground was parched. There was the heaviest rainfall recorded throughout the whole 11 years in the October following, but with hardly any result in the way of increasing the volume of water flowing down the river. The land was exceptionally dry, and consequently capable of absorbing and evaporating to the uttermost.

2983. (*Mr. Harrison.*) The diagram shows that September was an exceedingly dry month. Then comes the largest rainfall in October which does not cause a flood until the land becomes saturated after two or three months?—Yes, that is quite in accordance with the evidence received from Mr. Bailey Denton, that on some clay land which he occupied he found after that dry September it required 6 inches of rainfall before the ground was so saturated that it would pass any water by the under drains at a depth of about 4 feet 6 inches below the surface.

2984. (*Col. Harness.*) Will not the returns appear in the report of the Rivers Pollution Commission?—Yes, but as this Commission have taken up the subject, I have spoken to my brother Commissioners, and they are quite willing that you should be able to make any use of the returns you wish.

2985. (*Mr. Harrison.*) Those tables were prepared for the purpose of the report?—Yes; but if we have prepared anything that will forward the object of this Commission, you are welcome to it. After the ground is thoroughly saturated by a heavy and general rainfall, and after the rain has ceased, the gradual diminution in the volume of water passing down the Thames when shown on a diagram forms very nearly a regular curve; this I have represented approximately upon diagram No. 2. (*this the witness handed in. See Appendices A, D*). Diagram No. 2 shows the volume of water passing at each successive period during 240 days which would elapse subsequent to a heavy flood before the discharge of the river would be reduced to about 350,000,000 gallons per day.

2986. (*Mr. Prestwich.*) As you have only taken the rainfall at two points, at Kingston and Cirencester, have you found any anomalies to arise in the relation between the rainfall and the delivery of the river at Kingston from excessive local rainfall on any of the tributaries, such as the Kennet, the Colne, or the Wey?—I have not been able to examine that, but there is one striking feature that diagram No. 1 brings out, which is this, that when the rainfall is chiefly at Kingston, the river rises and also falls much more rapidly, apparently from the rain falling upon London clay and passing more rapidly down to the river. Diagram No. 2 would not apply to this; it would not be found sharp enough to represent a rainfall immediately in the neighbourhood of Kingston when there was no rain at Cirencester; in such cases the flood passes off very rapidly, in fact in a few days.

2987. (*Col. Harness.*) That is applicable to the general rainfall throughout the whole district?—Yes.

2988. (*Mr. Prestwich.*) I mean rather this, that in case of an excess of local rainfall in any of the tributary valleys, such as the valley of the Wey, or the Colne, or the Kennet, have you found that to interfere with the results given on this table?—I have

no information which would enable me to make any reliable observations upon that point.

2989. (*Mr. Harrison.*) Referring to Table No. 2, you explained the columns 1 and 2 as being the result of the rainfall over the 11 years, divided in the first column into the months between April and September and as between October and March, and the second column gives the yearly rainfall in inches?—Yes.

2990. From that it would appear that in 1866 the maximum rainfall of those 11 years was 36·42 inches?—Yes.

2991. And the minimum appears to have been in 1857, when it was only 22·76?—Yes.

2992. The average being, as has been stated already, 27¾ inches?—Yes.

2993. Taking the next as the calculated discharge at Kingston, that, I presume, is taken from the information which you have already put in as obtained from Mr. Simpson's observations?—Yes, reduced to inches over the whole area of the Thames basin.

2994. Therefore, that gives the discharge in inches at Kingston as being 9·25 inches out of the 27·74 inches?—Yes.

2995. Then the remainder is 18 inches?—It is not the exact remainder. The next two columns, half-yearly and yearly, are taken chiefly from the information given by Mr. Evans. You will observe there is this note: "The evaporation is calculated "from observations on percolation by Mr. Evans of "King's Langley, with an addition for extra eva- "poration from the clay in winter." There would of course be a larger evaporation from the clay than from the chalk.

2996. (*Chairman.*) Because of its retentive power? Yes, and the water lying longer and being more exposed. Mr. Bailey Denton's observations on the discharge from free soils and from clay soils clearly prove that there would be a larger evaporation from the clay during winter. Therefore, I have added as nearly as I could calculate it (and I have done it pretty carefully) the extra evaporation from the area of the clay basin.

2997. (*Mr. Harrison.*) Then going on to the fourth which is the volume added to or drawn from subterranean reservoirs half yearly, being plus or minus, I presume that column represents this, that where it is plus it must be due to taking a large amount from the chalk chiefly to make up the difference?—Where it is plus it shows that there was an addition to the subterranean reservoirs, and where it is minus it shows that the chalk gave out more than it received.

2998. Taking the whole of those calculations together, they account for the whole of the 27¾ inches?—Yes.

2999. When there has been a wet season, a portion of it is absorbed by the chalk or the oolite, or whatever the soil may be, and again in dry seasons is discharged from them, making up this plus or minus amount?—Yes.

3000. (*Col. Harness.*) Is plus and minus applicable to the reservoir or the river?—To the subterranean reservoir.

3001. When it is plus it receives?—Yes, it receives more than it discharges; at the commencement of the 11 years the discharge was about 500,000,000 gallons per day derived from springs, and at the end of the 11 years very nearly 1,000,000,000 gallons per day, showing that at the termination of the period of 11 years, the subterranean reservoirs held more water than they did at the commencement.

3002. (*Mr. Harrison.*) The rainfall in the year 1866 appears to have been the largest rainfall in the 11 years, being 36·42 inches?—Yes.

3003. I observe at the foot of the table a note which states that one inch of rain over the Thames basin gives 53,375,000,000 gallons of water?—Yes. I may put in probably with advantage this map which gives the acreage of the Thames basin (*handing in a map*). That is a copy of the map which is appended to our first report on the Thames. (*See Appendix V.*)

3004. (*Chairman.*) This is the result of a careful survey, is it not?—It is taken from Greenhough's geological map of England and Wales. I will now hand in Table No. 3.

The witness delivered in the following table:

No. 3.

TABLE showing approximately the RAINFALL on the THAMES BASIN; the DISCHARGE by the THAMES at KINGSTON; the EVAPORATION and the Addition or Subtraction from the SUBTERRANEAN RESERVOIRS in millions of gallons, Half-yearly and Yearly.—April 1855 to April 1866.

Date.	Rainfall.		Discharge at Kingston.		Evaporation.		Quantity added to or drawn from Subterranean Reservoirs.			
							Half-yearly.		Yearly.	
	Half-Yearly.	Yearly.	Half-Yearly.	Yearly.	Half-Yearly.	Yearly.	+	−	+	−
	Mills. of Gallons.	Mills. of Gallons.	Mills. of Gallons.	Mills. of Gallons.	Mills. of Gallons.	Mills. of Gallons.	Mills. of Gallons.	Mills. of Gallons.	Mills. of Gallons.	Mills. of Gallons.
1855–6 April to September, inclusive	697,077	1,409,633	118,365	474,618	552,972	842,007	25,740	—	93,008	—
1855–6 October to March	712,556		356,253		289,035		67,268			
1856–7 April to September	858,807	1,477,423	191,344	410,577	628,231	957,833	39,232	—	9,013	—
1856–7 October to March	618,616		319,233		329,602		—	30,219		
1857–8 April to September	704,016	1,214,814	170,319	402,034	682,675	1,005,871	—	148,978	—	193,101
1857–8 October to March	510,798		231,715		323,196		—	44,123		
1858–9 April to September	823,042	1,313,024	140,762	293,143*	610,082	1,056,042	72,198	—	—	36,161
1858–9 October to March	489,982		152,381		445,960		—	108,359		
1859–60 April to September	796,355	1,578,832	122,013	492,637	752,063	1,043,234	—	77,721	42,961	—
1859–60 October to March	782,477		370,624		291,171		120,682	—		
1860–1 April to September	1,052,021	1,743,761	359,752	849,475	611,684	900,719	80,585	—	—	6,433
1860–1 October to March	691,740		489,723		289,035		—	87,018		
1861–2 April to September	600,468	1,386,681	172,721	483,924	499,595	811,582	—	71,848	91,175	—
1861–2 October to March	786,213		311,203		311,987		163,023	—		
1862–3 April to September	907,375	1,531,862	327,526	598,404	672,531	1,041,630	—	92,682	—	108,172
1862–3 October to March	624,487		270,878		369,099		—	15,190		
1863–4 April to September	772,336	1,437,922	136,384	375,718	705,090	958,898	—	69,138	103,306	—
1863–4 October to March	665,586		239,334		253,808		172,444	—		
1864–5 April to September	509,731	1,251,109	147,517	364,974*	425,404	899,316	—	63,190	—	13,181
1864–5 October to March	741,378		217,457		473,912		50,009	—		
1865–6 April to September	789,950	1,940,917	126,779	586,914	672,531	1,177,067	—	9,360	176,936	—
1865–6 October to March	1,150,967		460,135		504,536		186,296	—		
	16,285,978	16,285,978	5,432,418	5,432,418	10,694,199	10,694,199	977,477	818,126	516,399	357 048
							* 159,351			

NOTE.—The rainfall is calculated from the averages of records kept by James Simpson, Esq., C.E., at Kingston, and T. Brown, Esq., at Cirencester.

The discharge is calculated from data supplied to the Rivers Commission by James Simpson, Esq., C.E.

The evaporation is calculated from observations on percolation by John Evans, Esq. of King's Langley, with an addition for extra evaporation from the clay in winter.

* The average daily discharge at Kingston between April 1858 and April 1859 was 803 million gallons per day.
" " " April 1864 " 1865 was 1,000 " "

J. T. Harrison, Esq.

9 May 1867.

3005. Will you explain table No. 3?—No. 3 is a similar table to No. 2, only instead of the rainfall discharge and evaporation being in inches they are given in millions of gallons.

3006. (*Mr. Harrison.*) For the purposes of this inquiry is not the most important point in this table the amount of the average yearly discharge over the 11 years at Kingston?—Yes.

3007. From this table it appears that the least amount was in the year 1858, when the quantity over the whole year amounted to 293,143,000,000 gallons?—Yes, that is the total quantity.

3008. The next smallest quantity appears to have been 364,974,000,000 gallons, was that the total quantity in the whole year?—Yes, in 1863 the volume discharged was 375,718,000,000 gallons. The rainfall during those three years was in 1858, 1,313,024,000,000 gallons; in 1864, 1,251,109,000,000 gallons; and in 1863, 1,437,922,000,000 gallons.

3009. Is that the total rainfall in the whole year?—Yes.

3010. Then there is the question of the actual discharge?—Yes, I have also a table which I think it would be well to mark No. 3A, which gives the number of days in each month during those three years when the water was lowest. It gives in the first column the number of days in each of those years when the volume of water discharged daily at Kingston was below 400,000,000 gallons per day; in the second column between 400,000,000 and 500,000,000 gallons per day, and in the third column between 500,000,000 and 600,000,000 gallons per day; in the fourth, between 600,000,000 and 700,000,000 per day, and so on. I take those three years, 1858, 1859, and 1864, as being the driest years during the 11 years, 1858 and 1859 being successive years which were the most important years as regards the water supply of the Thames. I will now hand in that table.

The witness delivered in the following table:

No. 3A.

TABLE showing the NUMBER of DAYS in the years 1858, 1859, and 1864, on which the VOLUME of WATER passing down the THAMES at KINGSTON was under 400,000,000 gallons per day:—

The number of days when the flow was between 400 and 500 million gallons per day
Ditto ditto 500 „ 600 ditto
Ditto ditto 600 „ 700 ditto
Ditto ditto 700 „ 800 ditto
Ditto ditto 800 „ 900 ditto
Ditto ditto 900 „ 1,000 ditto
Ditto ditto above 1,000 million gallons per day.

	Number of Days when the Volume was							
	Below 400 Million Gallons per Day.	Between 400 and 500 Million Gallons per Day.	Between 500 and 600 Million Gallons per Day.	Between 600 and 700 Million Gallons per Day.	Between 700 and 800 Million Gallons per Day.	Between 800 and 900 Million Gallons per Day.	Between 900 and 1,000 Million Gallons per Day.	Above 1,000 Million Gallons per Day.
1858.								
January	—	—	1	5	11	11	2	1
February	—	—	—	—	—	2	8	18
March	—	—	—	6	7	5	7	6
April	—	—	—	1	1	2	6	20
May	—	—	—	3	5	10	4	9
June	2	5	12	10	1	—	—	—
July	5	16	10	—	—	—	—	—
August	15	14	2	—	—	—	—	—
September	14	11	5	—	—	—	—	—
October	—	7	21	3	—	—	—	—
November	—	9	18	3	—	—	—	—
December	—	1	18	2	3	5	1	1
	36	63	87	33	28	35	28	55

There were 20 days in June, July, August and September when the volume of water flowing past Kingston-on-Thames was about 350,000,000 gallons per day.

1859.								
January	—	—	4	8	7	6	4	2
February	—	—	—	—	1	6	5	16
March	—	—	—	2	6	13	4	6
April	—	—	—	—	9	7	2	12
May	—	—	3	13	6	2	3	4
June	2	5	5	7	2	4	3	2
July	11	13	5	1	—	—	—	—
August	12	17	2	—	—	—	—	—
September	7	14	4	2	1	2	—	—
October	—	1	14	6	1	2	2	5
November	—	—	—	—	3	9	3	15
December	—	4	1	—	1	—	—	25
	32	54	38	39	38	51	26	87

There were 14 days in July, August, and September 1859 when the volume of water flowing past Kingston-on-Thames was about 350,000,000 gallons per day.

No. 3A.—TABLE showing the Number of Days in the Years 1858, 1859, and 1864, on which the Volume of Water passing down the Thames at Kingston was under 400,000,000 Gallons per Day—*continued.*

	Number of Days when the Volume was							
	Below 400 Million Gallons per Day.	Between 400 and 500 Million Gallons per Day.	Between 500 and 600 Million Gallons per Day.	Between 600 and 700 Million Gallons per Day.	Between 700 and 800 Million Gallons per Day.	Between 800 and 900 Million Gallons per Day.	Between 900 and 1,000 Million Gallons per Day.	Above 1,000 Million Gallons per Day.
1864.								
January	5	3	1	1	5	1	5	10
February	—	—	—	1	7	5	11	5
March	—	—	—	—	—	—	—	31
April	—	—	—	1	—	7	3	19
May	—	—	1	6	5	12	3	4
June	—	—	1	10	7	12	—	—
July	—	10	10	9	2	—	—	—
August	2	11	17	1	—	—	—	—
September	—	—	14	10	5	1	—	—
October	1	—	16	10	4	—	—	—
November	—	1	9	13	3	1	1	2
December	—	2	2	6	13	1	5	2
	8	27	71	68	51	40	28	73

There were two days in August 1864 when the volume of water flowing past Kingston-on-Thames was about 350,000,000 gallons per day.

3011. The result of that table is this, is it not, that in the year 1858, during the months of June, July, August, and September, there were 36 days in which the discharge at Kingston was below 400,000,000 gallons per day?—Yes, and you will see the note below, which is important; "there were 20 "days in June, July, August, and September when "the volume of water flowing past Kingston-on-"Thames was about 350,000,000 gallons per day."

3012. (*Col. Harness.*) Would not that be after the water companies had taken out the water?—No, it is above Kingston; the gaugings were taken at a point above the works of three of the water companies.

3013. (*Mr. Harrison.*) During the year 1859 there were again 32 days in which the supply was below 400,000,000 gallons daily?—Yes.

3014. And the note to that is, "there were 14 days "in July, August, and September 1859, when the "volume of water flowing past Kingston-on-Thames "was about 350,000,000 gallons per day"?—Yes.

3015. Taking the next year, 1864, it appears that there were only eight days in which the volume of water was below 400,000,000 gallons?—Yes; and five out of those eight are in January; that arose from severe frost; on two occasions in the year 1855, during the very severe frost, the volume of water flowing past Kingston was reduced to nearly 350,000,000 gallons.

3016. (*Mr Prestwich*) Have you given the mean delivery of the driest year—not any particular day—but dividing the year by the number of days and taking the mean of that year?—In the year 1857–8 the total discharge at Kingston was 402,034,000,000 gallons; that divided by 365 gives about as an average 1,100,000,000 gallons. The smallest average discharge was in 1858–9, being just 800,000,000 gallons per day.

3017. (*Mr. Harrison.*) It is stated at the bottom of Table No. 3, "The average daily discharge at Kings-"ton between April 1858 and April 1859," (which is the least discharge) "was 800,000,000 gallons per "day"?—Yes.

3018. And the average daily discharge in 1864, which was the next driest year, was just 1,000,000,000 gallons daily?—Yes.

3019. There appears to be an anomaly in this table which perhaps you may be able to explain; it appears that in the year 1857–58 the rainfall was 1,214,814,000,000, and the discharge at Kingston was 402,034,000,000 gallons; taking the next year the rainfall was 1,313,024,000,000 being in excess by nearly 100,000,000,000 gallons of the rainfall of the previous year; but the discharge at Kingston in that year appears to have been only 293,143,000,000; therefore there is a larger rainfall in 1858 than there is in 1857, but a larger discharge at Kingston in 1857 than there is in 1858?—Yes; I have no doubt that the diagram which I have handed in will explain it in a moment. You will observe that previous to April 1857 there was a considerable rainfall and a pretty full river (supplied chiefly from springs) throughout the summer; during the winter there was comparatively little extra discharge and a small rainfall, the rainfall which appears so large in the year 1858 occurred chiefly during the summer months, when the evaporation in such a year as that would be almost equal to the rainfall, and hardly a drop of the rainfall would find its way to the river.

3020. (*Mr. Prestwich.*) Have you not the gaugings of the different tributaries?—No, we had not the means of obtaining them. I do not think that they exist.

3021. (*Col. Harness.*) At the Colne you have got them, have you not?—No.

3022. Had not Mr. Simpson?—No; he only kept his observations for the purposes of the Chelsea and Lambeth Water Companies, to know what the volume of water passing down the Thames at Kingston was.

3023. Had not Mr. Evans?—No; he is at King's Langley, and he does not care at all what quantity goes into the river below him.

3024. (*Mr. Prestwich.*) The delivery of the different tributaries would vary, would it not, according to their soil?—No doubt. The value of this information I think is indicative of what it is desirable to obtain. If observations were made carefully at certain points in the river and its tributaries, the information would be valuable; such observations as those given by Mr. Simpson could scarcely be obtained respecting any other river. The only approximation to such information we obtained from Mr. Gott, borough surveyor of Bradford. Mr. Gott gave us the daily gauging of the flow of water from Many-Springs, which had been kept during the same period, from 1855 to 1866, and the rainfall in the immediate neighbourhood. He could not give us the area from which the spring water was collected as it was uncertain. But the similarity between the discharge from the springs at Bradford and of the Thames at Kingston is remarkable. This height (*pointing to the diagram*) shows the discharge from a spring at Bradford in Yorkshire simultaneously

T. T. Harrison, Esq.

9 May 1867.

with the discharge from the Thames at Kingston, and the diagrams correspond in a number of cases in a remarkable manner. Such a similarity at two points so far apart could hardly be expected.

3025. (*Mr. Harrison.*) Of course there are particular months in the year when we generally expect a rainfall?—Yes; this correspondence shows that the rainfall which soaks into the ground and comes out in springs is much more similar in different parts of the country than is generally imagined.

3026. (*Mr. Prestwich.*) In Table No. 3 you have divided the rainfall, the discharge at Kingston, and the evaporation, and then you have given the quantity added to or drawn from subterranean reservoirs; that, I presume, marks rather the quantity delivered by springs, independent of immediate rainfall on any particular day or month?—I think you will find what you want in the next table; it marks the difference. There is a certain amount of rainfall, there is a certain volume discharged at Kingston, and there is a certain quantity of water evaporated, and the plus or minus is the difference between the discharge and the evaporation added together and the rainfall.

3027. Then the two first columns give the positive quantities, and the third one is a hypothetical quantity?—The third one is not altogether hypothetical, it is drawn from observations within the Thames basin with a similar rainfall, or nearly so.

3028. Then in fact the quantity derived from the reservoirs would rather indicate that, notwithstanding a moderate rainfall, the quantity delivered from springs in the chalk would be added to that rainfall, and would maintain a greater uniformity of discharge than would otherwise happen?—There is not a doubt about it in some cases. Where there is a considerable plus quantity the reservoirs are comparatively full; the subterranean reservoir is exactly similar in character to an ordinary reservoir more or less full. If there is a surplus quantity it might be delivering 1,000,000,000 gallons per day, at another period when very heavily drawn upon, the subterranean reservoir might be only delivering 500,000,000 gallons per day, a comparison of the table with the diagram shows a remarkable coincidence. I will now hand in Table No. 4.

The witness delivered in the following table:

No. 4.

TABLE showing approximately the VARIATIONS in the VOLUME of WATER in the SUBTERRANEAN RESERVOIRS at the Termination of each Half Year, supposing there were 1,000,000 million gallons on April 1st, 1855:—

	Million Gallons. +	Million Gallons. −	Million Gallons.	Remarks.
1855, April 1	—	—	1,000,000	Heavy continuous rain in July for several weeks.
„ October 1	25,740	—	1,025,740	Do. in October.
1856, April 1	67,268	—	1,093,008	Heavy rain in May, August, and September.
„ October 1	29,232	—	1,132,240	Moderate winter rain.
1857, April 1	—	30,219	1,102,021	Steady summer rain.
„ October 1	—	148,978	953,043	Heavy rain in October, AFTERWARDS DRY WINTER.
1858, April 1	—	44,123	908,920	Do. in April. Steady summer rain.
„ October 1	72,198	—	981,118	Dry winter.
1859, April 1	—	108,359	872,759	June and September heavy rain.
„ October 1	—	77,721	795,038	Abundant winter rain.
1860, April 1	120,682	—	915,720	Very heavy summer rain.
„ October 1	80,585	—	996,305	Considerable winter rain, large quantity passed off in floods.
1861, April 1	—	87,018	909,287	
„ October 1	—	71,848	837,439	Very heavy and steady summer rain.
1862, April 1	163,023	—	1,000,462	Abundant winter rain.
„ October 1	—	92,682	907,780	Steady summer rain.
1863, April 1	—	15,490	892,290	Rain heavy October and January.
„ October 1	—	69,138	823,152	Heavy rain May and September.
1864, April 1	172,444	—	995,596	Do. October and March.
„ October 1	—	63,190	932,406	Very dry summer.
1865, April 1	50,009	—	982,415	Wet November and January.
„ October 1	—	9,360	973,055	Considerable rainfall May to August.
1866, April 1	186,296	—	1,159,351	Extremely wet winter.
	977,477	818,126		
	159,351			

3029. (*Chairman.*) Will you have the goodness to explain that table?—No. 4 is taken from Table No. 3, and shows in the third column what would probably be the condition of the storage in the subterranean reservoirs at the termination of each half-yearly period. There are also some observations opposite to each half year as to the rainfall during the half year.

3030. (*Mr. Harrison.*) You begin with the assumption that you have 1,000,000,000,000 gallons in storage on the 1st of April 1855?—Yes.

3031. And taking it from those preceding tables this would give you the plus or minus that quantity on the 1st of April and the 1st of October every year?—Yes.

3032. And with a note appended to it of the particular circumstances which may have influenced the plus or minus?—Yes.

3033. You also stated here in the year 1855 "heavy "continuous rains in July for several weeks," and "ditto in October;" and in 1856 "heavy rain in May, August, and September," the result of that being that there is a plus in each of those three years?—Yes.

3034. And the next being "moderate winter rain" brings a minus quantity, and then a "steady summer rain," also brings a minus quantity?—Yes, you may have a very heavy summer rain and really add very little indeed to the subterranean supply. The records both of Mr. Greaves and of Mr. Evans show that very frequently for a whole month none of the rainfall percolates through the subsoil to the lower stratum.

3035. (*Col. Harness.*) How do you get at the assumption of 1,000,000,000,000?—It is merely like the base line for a section. It is merely a quantity from or to which you may subtract or add. I will now hand in Table No. 5.

The witness handed in the following table:

No. 5.

THAMES RANIFALL and DISCHARGE.

	Inches.
Rainfall on Thames basin from 1st April 1855 to April 1st, 1866 (average between Kingston and Cirencester)	304·18
Or an annual average of	27·65

(*Note.*) The rainfall at Cirencester averages about 4·4 inches more than at Kingston.

There are three days on which rain falls at Kingston for two days at Cirencester.

The rainfall at Cirencester varied from - - 24·68 to 36·96 in 11 years.
The rainfall at Kingston varied from - - - 19·09 to 32·14 „

1 inch of rain over the Thames basin (area 102,480,000,000 square feet) gives 53,375 million gallons of water.

	Million Gallons.
Volume of water from rainfall over the Thames basin from April 1855 to April 1866 -	16,285,978
Volume of water discharged by Thames, calculated from Mr. James Simpson's data -	5,432,438
Difference - - - -	10,853,540
The daily volume discharged April 1855 was 500 million gallons, and April 1866 1,000 million gallons per day. If no rain fell it would take 150 days for the Thames discharge to fall from 1,000 million gallons to 500 million gallons per day. There was therefore a store in the subterranean reservoirs of at least 750 million gallons × 150 days in April 1866 in excess of April 1855, -	112,500
Leaving evaporated, &c. - -	10,741,040
The volume evaporated from the Thames area, were it all chalk, would according to Mr. Evans' percolation observations be about -	9,859,000
Leaving - - - -	882,040

The extra evaporation from the clay surface of the Thames basin would fully account for this.

3036. (*Chairman.*) What is the object of Tables No. 5?—It brings under view some of the results derivable from the tables which I have already given. I will also hand in Table No. 6.

J. T. Harrison, Esq.

9 May 1867.

The witness delivered in the following table:

No. 6.

DISPOSAL of THAMES RAINFALL, April 1855 to April 1866.

	Million Gallons
Evaporation, &c. - - - -	10,694,209
Discharged { In floods - - -	2,665,818
Discharged { From springs - - -	2,766,600
Reserve in subterranean reservoirs, April 1866 in excess of April 1855 - - -	159,351
Rainfall - - - -	16,285,978

PROPORTIONS.

Evaporated - -	2/3		= 66 per cent.
Passed off from springs - -	1/6	1/3 discharged	= 17 „
Passed off in floods -	1/6		= 17 „

EVAPORATION.

10,694,209 million gallons evaporated in 11 years, 972,200 gallons per annum, or an average of 18·21 inches per annum, varying from 15 inches in 1861 to 22 inches in 1865–6.

3037. (*Mr. Harrison.*) This table, No. 6, professes to give the disposal of the Thames rainfall from April 1855, to April 1856, and is not this the effect of that table, that the evaporation is 10,694,209,000,000 gallons?—Yes, during the whole period.

3038. Discharged in floods, 2,665,818,000,000 gallons, and from springs, 2,766,600,000,000 gallons?—Yes, I should like to explain how those are divided. On diagram No. 1 a line was drawn representing the discharge from springs, all above that line was considered as being discharged from the surface as flood water. Very nearly half the water passed off in the form of flood-water from the surface, and the other half in the whole 11 years appears to have been derived from springs.

3039. The result arrived at from this table, No. 6, appears to be that two-thirds of the rainfall was evaporated, that one-sixth passed off in floods, and one-sixth was discharged from springs?—Yes, two-thirds evaporated and one-third discharged.

3040. (*Col. Harness.*) You would not apply that evaporation of two-thirds, would you, to a place where the rainfall was very much larger?—Certainly not; each district requires to be considered specially. In the mountainous districts of Wales and Cumberland, the rainfall is so much larger, the surface contours, and subsoils (granite, clay, slate, &c.) so different, that I have very little doubt that the evaporation is actually less in inches of depth of rainfall. There you have less pervious stratification, frequently bare and generally very steep, so that the water falling upon it passes rapidly away, and there is very little water left to be evaporated. Besides in such districts the atmosphere is much more humid, so that there is less evaporation. I have no doubt that the evaporation from a mountainous district is much less in actual inches than it is in a district such as the Thames; and as there is a greater rainfall in Wales and Cumberland, the proportion is much larger between the total rainfall and the evaporation.

3041. (*Chairman.*) What is Table No. 7?—Table No. 7 shows the area in square miles of the several geological strata which occupy the surface of the basin of the Thames and its tributaries above Kingston.

The witness delivered in the following table:

No. 7.

TABLE showing the AREA in Square Miles of the several GEOLOGICAL STRATA which occupy the Surface of the BASIN of the THAMES and its TRIBUTARIES above Kingston.

Name of Tributary.	Thames gravel.	Bagshot Sand. Upper.	Bagshot Sand. Middle.	Bagshot Sand. Lower.	London clay.	Plastic clay.	Chalk.	Upper greensand.	Gault.	Lower greensand.	Wealden clay.	Portland stone.	Kimmeridge clay.	Coral rag.	Oxford clay.	Cornbrash.	Forest marble.	Great and inferior oolites.	Fullers earth.	Upper and lower lias clay.	Marlstone.	Total square miles.
Thames above Oxford	–	–	–	–	–	–	–	–	–	–	–	1	1	13	148	17	56	44	–	–	–	280
Churn	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	3	6	30	5	2	–	51
Coln	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6	5½	12½	33	4	3	–	64
Windrush	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14	4½	7	83	7¾	19	–	135
Evenlode	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9	6	4	85	–	66	–	170
Cherwell	–	–	–	–	–	–	–	–	–	½	–	¾	1¾	10	86	32	–	52	–	80	84	347
Ray	–	–	–	–	–	–	2	½	1½	½	–	⅜	14	5	7	–	–	–	–	–	–	31
Cole	–	–	–	–	–	–	7½	1½	9	1¼	–	–	10	12½	10	–	–	–	–	–	–	52
Thames, Oxford to Wallingford	–	–	–	–	–	–	¼	33½	17	9¼	–	½	15	5⅛	2½	–	–	–	–	–	–	84
Ock	–	–	–	–	–	–	9	6	18½	4½	–	–	27	37	–	–	–	–	–	–	–	102
Thame	–	–	–	–	–	–	41	21	84	8	–	26	64	20	20	–	–	–	–	–	–	284
Thames from Wallingford to Windsor	30	–	–	–	29	31	291	–	–	–	–	–	–	–	–	–	–	–	–	–	–	381
Kennet	–	–	2	36	62	42	294	11	–	–	–	–	–	–	–	–	–	–	–	–	–	447
Colne	64	–	–	–	43	27	262	–	–	–	–	–	–	–	–	–	–	–	–	–	–	396
Loddon	12	21	44	27	110	11	64	–	1	–	–	–	–	–	–	–	–	–	–	–	–	290
Wey	24½	6½	30	39	27	4	50	126	18	11	26	Tunbridge Sands				–	–	–	–	–	–	362
Mole	9	–	½	5½	15	1½	27	3½	3½	16¾	79	17¾	–	–	–	–	–	–	–	–	–	179
Thames below Windsor	14½	–	–	–	6½	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	21
	154	27½	76½	107½	292½	116½	1,047¾	202¾	152½	52½	105	40¾	132¾	103	307½	67¾	85½	327	16¾	170	84	3,676

IMPERVIOUS STRATA.

	sq. miles.	
London clay	292½	Total 1,233½ sq. miles, or 34,388,006,400 sq. feet.
Plastic clay	56½	
Gault	152½	
Wealden clay	105	
Kimmeridge clay	132¾	
Oxford clay	307½	
Fuller's earth	16¾	
Lias	170	

PERMEABLE STRATA.

SHALLOW.	sq. miles.	
Thames gravel	154	Total 730½ sq. miles, or 20,358,201,600 sq. feet.
Plastic clay	60	
Upper greensand	76¾	
Lower greensand	52½	
Portland stone	40¾	
Coral rag	103	
Cornbrash	67	
Forest marble	85½	
Marlstone	84	

Source of perennial springs.

DEEP.	sq. miles.	
Bagshot sands	211½	Total 1,712 sq. miles, or 47,734,790,400 sq. feet.
Chalk	1,047¾	
Wey upper green sand	126	
Great & inferior oolites	327	

TOTALS.

	sq. miles.		sq. feet.
Impervious strata	1,233½	=	34,388,006,400
PERMEABLE			
Shallow	730½	=	20,358,201,600
Deep	1,712¾	=	47,734,790,400
	3,676	=	102,480,998,400

NOTE.—The areas of the impervious and permeable strata of the Plastic clay formation are corrected in the above table as suggested by Mr. Prestwich.

3042. (*Mr. Harrison.*) This table is divided in the first place into the Thames gravel, the Bagshot sand in three deposits, the London clay, the plastic clay, the chalk, the upper greensand, the gault, the lower greensand, &c., in fact it gives the whole of the different sections resulting in a total of 3,676 square miles above Kingston?—Yes.

3043. The area appears to have been divided by you again into impervious strata containing 1,293½ square miles, consisting of London clay, plastic clay, gault, Wealden clay, Kimmeridge clay, Oxford clay, fuller's earth, and lias?—Yes, probably Mr. Prestwich will correct me in putting plastic clay as being all impervious; I believe it is not quite so, I remember from reading his work he shows that it is not so, but still the area of the plastic clay is inconsiderable, 116½ square miles, and a large portion of it is impervious. I could not eliminate it, and therefore I put it all as impervious.

3044. Then the permeable strata are divided into that which is shallow and that which is deep, making the shallow 670¼ square miles, and the deep 1,712 square miles, the total result being impervious strata 1,293½ square miles, and the permeable shallow 670¼ square miles, deep 1,712 square miles?—Yes. The object in dividing it into deep and shallow, I may mention is this: there are large masses of chalk adjoining the Thames (which is an outlet for the springs for a considerable distance,) rising 500 or 600 feet above Ordnance datum, and 400 feet above the Thames itself, which give out water with great regularity. One of the facts mentioned by Mr. Evans is that he found water passing through the chalk descended about six feet per day. When rain falls upon the surface, a large portion of it evaporates, and the remainder passes into the subsoil; but it takes a long time before it passes from the surface to the subterranean reservoir, which extends many miles away from the point of discharge. Thus a considerable time elapses before it reaches the Thames where it is discharged, and the result is a much more steady and continuous flow from those deeply seated springs than from the shallower springs in the oolite district.

3045. (*Mr. Prestwich.*) That is to say, in the chalk district it takes several months before the rainfall is delivered into the shape of springs?—Exactly so.

3046. I see that in your table you have taken the Thames gravel as representing an area of 154 square

miles, is that taken from the Ordnance Survey?—Yes.

3047. Have you subtracted that from the area where that gravel covers either the London clay or the Bagshot sands?—Yes, I have taken it *per se*.

3048. I think that on the Ordnance map the gravel covering the Bagshot sands is not represented?—No doubt there is a considerable area of the Thames basin which is covered with gravel besides that which is mentioned here; but I had not the means of estimating it. A good deal of the London clay and of the Bagshot sands also is covered. I thought it was of importance to test the accuracy of Mr. Clutterbuck's views as to the rise of the water in the chalk from the Thames or any other point where it finds egress, and with that object I went from Reading to Nettlebed, about 8½ miles from Reading, and took the heights of several wells with the aneroid and measured the depths to the water. This section (*producing the same—see Appendix A, E*), shows the result, the surface of the ground, and the depth to the water in the wells at Nettlebed, Highmore Hill, Kidmore End and Caversham are plotted on it, and they give as the general result, that below the line coloured blue on the section the chalk is saturated with water.

3049. How many feet per mile of rise does it give?—It gives a rise on the average of 20 feet per mile. In the lower part it was about 7 feet per mile, and in the upper part about 37 feet per mile. That confirms generally Mr. Clutterbuck's view. We know that the Thames water is very hard, and we know that it obtains much of its hardness by passing through the chalk; the chalk, as the water passes through it, must year by year become more porous as the carbonate of lime is taken away from it; the chalk adjoining the Thames at Caversham near Reading (*pointing to the map*), through which all the water issuing at that point has to pass, must be more porous than the chalk in the neighbourhood of Nettlebed, eight miles distant, through which only the water falling upon the surface above it passes. The chalk at Nettlebed, would consequently be able to hold the water at a higher level, and it might be expected that the line of saturation should under those circumstances rise at a higher gradient as you receded from the Thames than it would in the neighbourhood of the Thames. That struck me as being a philosophical conclusion, and observations appeared to confirm it.

3050. That might arise, might it not, from several causes, from the larger size of the fissures through which the water would be discharged owing to the length of the valley, and again also from the lower chalk at Nettlebed being denser?—Yes; however, that is a subject that wants investigation, and which would well repay further observation.

3051. It shows how large the reservoir held in the chalk is for a gradual delivery into the Thames?—Yes.

3052. And it shows how important to the uniform discharge of the river it is to have a large formation of permeable strata, such as chalk, for the constant supply of the springs?—Yes, the level of the water at Nettlebed above the Thames is 300 feet, and you have in fact a kind of inverted reservoir with water 300 feet deep eight miles from the Thames.

3053. The delivery of which would continue until it was reduced to such a level as that the resistance of the strata would cause the flow to cease throughout a continued period of dry weather?—Yes, when the gravity of the water and the capillary attraction of the chalk in which it is held are equal, there would be a cessation of the flow, but it does not appear even when there is no rain for 240 days after a heavy rainfall, that this limit is nearly attained; the discharge then becomes almost uniform; so that it would probably be a long time before it was very much below 350,000,000 gallons per day. I may state that in making observations on the flow of the Thames between Wallingford and Maidenhead, where the Thames passes over chalk for a considerable distance, I found that there was an accession of water amounting to about 80,000,000 gallons per day insensibly coming into the river through its bed.

3054. Therefore, you consider such an area as that very important as maintaining the uniform flow of the Thames?—Undoubtedly.

3055. As rendering it very independent of the immediate rainfall of any particular month?—Undoubtedly; and much more important with regard to the uniform flow of the Thames than the oolitic district, which is generally shallow. The discharge from the oolite springs is rapid, and comparatively much larger during the winter months in consequence of their shallowness than those from the chalk, and much less during the summer months. The Thames, when I gauged it in September 1865, discharged only about 10,500,000 gallons from the oolitic district, whereas the discharge from the chalk below was 80,000,000 gallons per day directly into the bed of the Thames.

3056. You mean from the chalk between Wallingford and Reading?—Between Wallingford and Maidenhead.

3057. And delivered into the Thames by springs along the banks of the Thames and not by any rivers?—Just so.

3058. Do you think it would be possible to intercept those springs as they flow into the Thames from the body of the chalk?—I think it quite possible by driving into the chalk for some miles at a lower level than the subterranean reservoirs you would get a great deal of water and you might have the discharge from that source under control. In fact the system is adopted to some extent now upon the river Lea. The New River Company pump a large volume of water from wells, and the volume they so pump is largest in quantity when the river is lowest and they thus have recourse to the residuum which would not flow into the river in very dry seasons. I think it would be quite possible in the same manner to tap the chalk reservoir and keep the discharge under control, simply drawing upon it when required.

3059. (*Mr. Harrison.*) Making use of it as a natural reservoir?—Yes.

3060. (*Mr. Prestwich.*) Have you any measure of the springs from the Bagshot sands?—No; I am sorry to say I know very little, excepting from your work upon the subject.

3061. Amongst the shallow permeable strata I see you include a large portion of the oolite, you include the Coral rag and the Portland stone?—Yes. In the upper Thames the strata are very much dislocated, so that in hardly any case is there a large mass of the great oolite rising to a great height above the springs.

3062. By "shallow" you do not mean the absolute depth in feet, but you refer to the rapid delivery of the water that falls upon it?—Yes, it is tantamount to that.

3063. You would refer the permanent supply of perennial springs to the deeper permeable strata, such as the chalk, the upper greensand in the west of the greensand district?—Yes.

3064. With regard to the great and inferior oolites and the Bagshot sands, to which of them should you attach most importance?—Undoubtedly to the chalk. I believe that the chalk is the great source of the steady supply of the Thames. I will now beg leave to hand in Table No. 8.

The witness delivered in the following table:

T. Harrison, Esq.

9 May 1867.

No. 8.

GEOLOGY of THAMES BASIN above WATER COMPANIES WORKS at KINGSTON.

			Permeable strata.	Impervious strata.	Totals.
			Sq. miles.	Sq. miles.	Sq. miles.
	Oolite Division.				
The water from this division is conveyed to the Thames by the Churn, Colne, Leach, Windrush, Evenlode, and Cherwell.	Marlstone - - 84 sq. miles Great and inferior oolite 327 „ Forest marble - - 85½ „ Cornbrash - - 67¾ „	Permeable strata -	564¼	—	751
	Upper and lower lias - 170 „ Fuller's earth - - 16¾ „	Impervious -	—	186¾	
	Oxford Clay Division.				
The water from this division is collected by the Ray, Cole, Ock, and Thame; all of these receive some water from the outcrop of the chalk.	Coral rag - - 103 sq. miles Portland stone - - 29 „ Lower greensand - 24¾ „	Permeable strata -	156¾	—	726¾
	Oxford clay - - 307½ „ Kimmeridge clay - 132¾ „ Gault - - 129¾ „	Impervious -	—	570	
	Chalk Division.				
Almost all the chalk water is gathered by the Thames, Kennet, and Colne.	Chalk - - - - -	Permeable -	907	—	907
	Hastings and Bagshot Sands and London Clay Division.				
The water from this division is brought to the Thames by the London (Whitewater, Blackwater), Wey, Mole (which is sometimes nearly dry).	Tunbridge sands - 17¾ sq. miles Lower Greensand - 27¾ „ Upper Greensand - 202¾ „ Chalk - - - 140¾ „ Plastic clay - - 60 „ Bagshot sands - - 211½ „ Thames gravel - - 154 „ Wealden clay - - 105 „	Permeable -	814½	—	1,291¼
	Gault - - - 22¾ „ Plastic clay - - 56½ „ London clay - - 292½ „	Impervious -	—	503¾	
	Permeable strata - - -		2,442½	—	3,676
	Impervious strata - - -		—	1,233½	

3065. (*Chairman.*) Table No. 8 is a continuation of the previous sheet, is it not?—Yes. If you will be kind enough to look at the map of the Thames basin you will perceive that the strata run very nearly parallel. The part coloured yellow is the Oxford clay; over the whole of the area occupied by the Oxford, Kimmeridge, and Gault clays there is really very little supply from perennial springs. The Thames, which discharges at Dorchester I found in 1865 all but dry; it is sometimes very much flooded indeed, but in dry weather it hardly discharges any water. The upper district is oolitic, the middle district is the chalk, with the Thames winding through it for a very considerable distance. The Thames basin is divided in the last table into these four divisions; the Oolite, the Oxford clay, the Chalk, and the Bagshot sands and London clay. Opposite to each division are placed the tributaries which drain them.

3066. (*Mr. Prestwich.*) Where you are speaking of the drainage area of the Thames do you include all the tributaries of the Thames as low as Kingston?—Yes, all that discharge above the point from which the water companies take their water.

3067. Including the Wealden area as well as the Thames gravel proper?—Yes.

3068. It has been mentioned in evidence by one of the witnesses that if wells were sunk in any of the chalk valleys, such wells must rob the streams of a certain quantity of water, but that would necessarily be the case in whatever way the water was taken, whether taken from wells or from drainage area?—Yes, certainly, you might rob the wells with impunity during a very dry season without very much diminishing the existing flow into the river if the wells were sufficiently distant from the river. It would have the effect of generalising the withdrawal from the subterranean reservoirs throughout the whole year, the discharge would not be so large during the winter months in consequence of the deficiency of water in the subterranean reservoir, and this deficiency would be restored by the winter rain.

3069. It would only be a question of whether the water was taken after passing into the subsoil and delivered by springs, or taken directly it fell upon the surface?—Merely so, so far as the effect upon the rivers.

3070. That is to say, if the water was taken in drainage areas as at Manchester it would only be taken directly at the source instead of passing through permeable strata and through chalk, and delivered in springs the result would be the same?—Yes.

3071. (*Chairman.*) You are desirous, are you not, to call the attention of the Committee to some evidence which was given by Mr. Beardmore before the Pollution of Rivers Commission with reference to the rainfall?—I think that is almost embodied in the tables. Mr. Beardmore stated in evidence that the minimum discharge in 1858 in the river Lee during that very dry season was 18,657,000 gallons per day, and that the New River Company took about 18,000,000 gallons a day; this gives a total minimum flow of about 36,657,000 gallons per day; and he gave us evidence, also, that in September 1865 the flow altogether, the New River and the Lea, at Kingsweir was 4,550 cubic feet per minute, or 40,550,000 gallons. The discharge from the Thames calculated in proportion to their respective areas would give a minimum about 370,000,000 gallons of water per day.

3072. Has your attention been directed to the mode of distributing water in towns, especially in the metropolis?—We have had evidence upon that point both from Mr. Muir, the engineer of the New River Company, and from Mr. Greaves, the engineer of the East London Company; Mr. Muir stated to us in the evidence which I have laid before the Commission at question 1221, that in some model lodging houses

only seven gallons per head per day were used with virtually a constant supply of water, as the consumers had a large cistern which was never emptied.

3073. His answer is, "From experiments which I "made some years ago in model lodging houses I "found that their actual requirements, allowing them "to take as much as they required, did not amount "to more than seven gallons per head per day, but "rather less; a great deal more than that is allowed "them?"—Yes, that is his answer. Again, if you look at question 1231, you will see that he considers the supply might be reduced to 15 gallons per head throughout the district if proper provision were made to prevent waste.

3074. (*Mr. Prestwich.*) Was that including all purposes?—No, I assume that that was for domestic supply. At question 1183 Mr. Muir gives us this evidence, that his company supply 112,000 houses, and at question 1189 he says, that the population is about 7½ persons per house, that gives a population of 840,000.

3075. He says, I think, that the average of the whole of the metropolis is 8½ persons per house?—Yes, but in their district it is 7½, it is rather a better district than some others in that respect. At question 1198 he gives as the quantity of water used for trade purposes 2,300,000 gallons per day on an average, the total supply being 22,500,000 gallons, there are left for domestic purposes 20,200,000 gallons per day, giving 24 gallons per head per day as the supply for all except trade purposes, so that the reduction to 15 gallons would be from 24 gallons per head. But if you look at questions 3095 and 3096 he puts the consumption at 30 gallons per head, and he states that the difference between that and the 7 gallons per head, which he finds sufficient in the case of the model lodging houses, is wasted through defective ballcocks and other apparatus.

3076. (*Chairman.*) I presume that he means through the apparatus being defective or being tampered with?—Yes; then at question 1231 you will observe he says that he does not consider it would be any disadvantage to the New River Company if they were obliged to afford a constant supply, and that the quantity per head might be reduced to about 15 gallons if they had proper means to prevent waste. The evidence of Mr. Greaves, the Engineer of the East London Company, is very nearly to the same effect. At question 295 he gives the number of houses as 90,000, and at question 1019 he gives eight persons per house as the average. That gives the population supplied by the East London Water Company as about 720,000; at question 193 he gives 20,000,000 gallons as the volume delivered, that would be 28 gallons per head for all purposes. In the appendix to his evidence, you will see it mentioned that for trade purposes they supply 5,000,000 gallons per day, which reduces the supply for domestic purposes to 15,000,000 gallons per day, or 21 gallons per head. He states at questions from 1016 to 1020 that there are very large districts that do not take more than from 60 to 120 gallons per house per day, which with an average of eight persons per house works out to about 8 to 15 gallons per head; and he says at question 1017 that a constant supply would not be more distressing to the water company than an intermittent supply, if proper power were given to them to look after the consumption. I may mention that we found at Bradford in Yorkshire the supply per head was 15 or 16 gallons, and in some towns it was 12 gallons per head for domestic purposes, with no restriction put upon the quantity used.

3077. What was the average consumption per head?—15 or 16 gallons. At Halifax, with a population of 92,000, the quantity per head was 12 or 13 gallons for domestic purposes. At Leeds, for domestic supply which is constant, and watering the streets, the quantity is 16 gallons per head.

3078. (*Mr. Prestwich.*) From those facts have you formed any opinion as to what would be a sufficient supply per head in London?—The evidence that we have received appears to point distinctly to about 15 or 16 gallons per head, being an ample supply for domestic purposes, including waterclosets and watering streets.

3079. What per-centage would you add for trade purposes?—That varies in every town.

3080. What would it be, speaking of London?—I cannot say. I presume that the East London Water Company supply as much in proportion as any company for trade purposes. In Bradford and some of the towns in Yorkshire the first object is a good supply for manufacturing purposes, the supply for domestic purposes is a secondary object.

3081. (*Chairman.*) Do you think that 25 gallons per head would be sufficient both for domestic and trade purposes?—I am not prepared to say that. According to the information received from the east of London, taking that as a guide, that would be more than sufficient.

3082. (*Mr. Prestwich*). Would not the wants of the east of London be more than the average trade requirements of the metropolis?—There is no doubt about it.

3083. (*Mr. Harrison.*) In large houses, taking the west end of London, where baths are used extensively, and where perhaps there are many circumstances that cause a large consumption of water, you find that the consumption per head is a good deal more than that, do you not?—On our inquiry on the Aire and Calder, Mr. Filliter, of Leeds, gave us information as to the quantity of water that he himself consumed in his house with a family of 10. He said that he used 300 gallons per day—that is 30 gallons per head; he had taken the quantity by meter and had carefully examined it. He went into a detail of the mode in which this was consumed, and it appeared that he had two baths, one holding about 70 gallons, and the other about 80 gallons, one he filled twice a day and the other once a day. Consequently 230 out of 300 gallons were used in the baths, the remaining 70 being sufficient for all other purposes, or 7 gallons per head upon his family of 10. That instance shows the enormous consumption there may be in the use of baths.

3084. (*Mr. Harrison.*) The present quantity of water taken from the Thames above Teddington Lock is about 60,000,000 gallons a day, is it not?—Mr. Simpson mentioned last spring that 60,000,000 was the largest quantity that had ever been taken up to that date; in December last the quantity taken was 48,000,000, and 42,000,000 gallons were taken from the Lea.

3085. Have not the companies the power under their existing Acts of taking 50,000,000 gallons more than that?—They have the power of taking 100,000,000 gallons altogether.

3086. It would appear from the information which you have given us, that taking the driest year there have been only 36 days in which the supply passing Teddington Lock, or passing Kingston has fallen below 400,000,000 gallons a day?—Yes, that is the only case during 11 years.

3087. In the year 1858 there were 36 days; in the year 1859 32 days, and in the year 1864 eight days?—Yes, five of those eight being during severe frost.

3088. Then during the remainder of the 11 years there does not appear to have been any period in which it has fallen to so low an amount as 400,000,000 gallons a day?—I can hardly say that, but those are the most striking periods.

3089. Assuming that a larger quantity were taken from the Thames above Teddington Lock, the only injurious effect of that would be between Teddington Lock and, perhaps, Putney, or the point to which at neap tides the tide will flow?—Yes, from the evidence we have it affects the Thames to some extent between Teddington Lock and Putney; above Teddington Lock the water may be kept up to a considerable height by boards.

J. T. Harrison, Esq.

9 May 1867.

3090. It would merely affect the question as regards the navigation practically between Putney and Teddington Lock?—Yes, that portion of the river is now navigable only with the tide; at low water it is not navigable.

3091. Has your attention at all been given to any serious effect which the abstracting of so large a quantity of water would have upon the Thames below Teddington, has that formed a portion of your investigation?—Captain Burstal informed us that the volume of water going down would have no effect upon the sands lying at the mouth of the Thames; and he said that the shoals through London dredged of late years were found to be to a very great extent clay, and not sand, so that when once the Thames was well cleansed out, and the embankments made, he did not consider there would be much deposit. I do not imagine that the water from above Teddington has very much to do with the scouring of the Thames below, except during heavy floods.

3092. Supposing it should at any time be determined to take an extra 100,000,000 gallons from the Thames, and it were at the same time found that it was necessary to provide for those special occasions on which the flow would be reduced below 400,000,000 gallons, have you considered whether there would be any difficulty in making provision by reservoirs in the higher reaches of the Thames to supply the requisite quantity during the periods of deficiency?—I believe reservoirs might be made in the upper districts of the Thames which would supply a very large deficiency in very droughty seasons; it is merely a question of the expense of carrying them out.

3093. Would not the space upon which any reservoirs could be made, be naturally governed, first of all by the necessity of placing them upon impervious strata, such as part of the Oxford clay and the London clay. Of course you could not make such reservoirs upon the chalk?—No, of course not.

3094. You have not gone into the question to see whether such reservoirs might be made as would supply that deficiency in times of drought?—I have gone into it to some extent, but not very minutely.

3095. Assuming in all these cases that the money was allowed to be expended, could such a supply be obtained by carrying drifts to a large extent into the chalk?—I think that it very probably might, the volume that you might get from a drift is determinable in the same manner as the volume that you can get from a well. It is restricted in quantity by the length and breadth of the drift, and questions of that kind; by carrying a sufficient number of drifts and having them under control, I think a supply could be at command, so as to keep up the flow of the Thames at Kingston to one uniform volume of 500,000,000 or 600,000,000 gallons per day.

3096. (*Chairman.*) When you speak of having those drifts under control, do you mean that you would stop up the ordinary outlets of the chalk?—No, not the outlets of the chalk, but the outlet of the drift when you do not want it.

3097. How would that act with regard to the storing power, because that must be fed by the rainfall?—Yes, no doubt the storage must; the chalk is as completely a reservoir as any artificial reservoir in the country.

3098. It takes it up as a sponge?—Yes, and it is quite possible to tap that reservoir just as you can an ordinary artificial reservoir, keep the discharge from it under control, and open your sluices and let the water flow out as you please.

3099. Supposing you had a very dry season, and were to tap that reservoir, you would have no surface supply?—That is the point; I believe that if the drifts were carried into the chalk with judgment, you might draw water from that part of the chalk in a very dry season without seriously affecting the discharge from other sources throughout the dry season into the Thames itself.

3100. (*Mr. Harrison.*) You form that opinion upon data which have been ascertained as to the rate at which the water travels through the chalk, namely, about six feet per day?—Yes, at the rate of six feet per day it passes from the surface downwards perpendicularly. I do not know at what rate it travels horizontally towards the outlet.

3101. (*Chairman.*) Have you observed any points in the area of the Thames which would be peculiarly adapted for the formation of surface reservoirs?—Above Oxford there is a large area of ground on each side of the river on the Oxford clay where reservoirs of a shallow character might be formed. I may mention that Professor Phillips suggested, when he gave evidence before our Commission at Oxford, that in the upper part of the Thames a system might be adopted of embanking the outlets of some of the tributaries so as to, as it were, throw back into the oolites and other permeable strata, a large volume of water, and have the discharge from the subterranean reservoirs in that way under control. It is quite a question whether that might not be done with success. He mentioned a case in which a friend of his in Yorkshire had adopted the plan of banking up a spring and forcing the water back into the permeable strata behind, and whereas the spring used occasionally to fail in very droughty seasons, he afterwards had a constant supply, as in that way he made the strata below the surface his reservoir. The only difficulty in the case of the upper Thames is that the tributary of the Severn which passes upwards from Stroud cuts much more deeply into the stratification than the tributaries of the Thames.

3102. You mean on the other side of the watershed?—Yes, and that if you back the water into the strata it is not at all improbable that you would be doing that to the benefit of the manufacturers of the Stroud valley.

3103. (*Mr. Harrison.*) I presume there is no doubt that a portion of that which now fills the Thames basin would find its way into the Severn?—Precisely so, as far as subterranean water goes the mere watershed is not the limit of the water supply, at least not invariably so.

3104. (*Mr. Prestwich.*) You stated, did you not, that during a portion of the year the quantity of water which passes by Kingston is above 1,000,000,000 gallons a day?—Yes.

3105. (*Mr. Harrison.*) In the year 1858 it appears to have been for 55 days above 1,000,000,000, then in the year 1859 it was the same for 87 days, and in 1864 the same for 73 days, those being the three driest seasons?—Yes.

3106. (*Mr. Prestwich.*) That is to say, there are a certain number of days in the year when the quantity passing by Kingston exceeds 1,000,000,000 gallons a day?—Yes.

3107. Would it not be possible to store a certain quantity of that water in reservoirs dug in the London clay between Windsor and Kingston?—I cannot say, but I think it very probable; there is a great deal of Thames gravel which is very porous.

3108. Supposing the Thames gravel to be from five to 12 feet thick, which is about the utmost thickness, with the London clay underlying it, would it be possible to form reservoirs in such gravel?—If the gravel is so shallow there would be no difficulty in doing it. Such reservoirs would be similar to those which have been constructed recently by the East London Waterworks Company in the Lea valley, the depth of which is not very great. There is a great fall on the Thames. Teddington Lock is about 24 feet above Ordnance datum. Henley-on-Thames, 40 miles from London, is 100 feet. Caversham, near Reading, is 125 feet above datum, 76 miles. Wallingford is 153 feet above datum, 94 miles. Sandford, near Oxford, is 186 feet above datum, 112½ miles. Godstone Lock is 201 feet above datum, 121 miles. Saint John's Lock, near Lechlade, is 245 feet above datum, 147 miles. Cricklade is 272 feet, 159 miles up, and Cirencester, 360 feet above datum, a distance of 166 miles from London.

3109. Would not it be possible to construct a reservoir in the neighbourhood of Abingdon, where there is little or no gravel?—Yes, all over that middle clay district there would be no difficulty. Possibly on the Thame there might be some suitable reservoirs constructed, they would be shallow, there would be no very deep reservoirs. Perhaps I may be allowed in further reply to question (3055) to mention that Mr. Stacy at Oxford gave us evidence that the ordinary winter discharge at Oxford was about 320,000,000 gallons per day, whereas at Kingston it is between 800,000,000 and 900,000,000 gallons per day, about one-third coming from the oolite which is shallow and extremely free. In summer at Oxford the ordinary discharge is about 73,000,000 gallons per day, and at Kingston the ordinary discharge is about 600,000,000 gallons per day, the part from above Oxford being only about one-eighth instead of one-third as in winter. This shows the rapid discharge during winter from the heavy rainfall on the oolitic district as compared with the steady discharge from the chalk throughout the year. The area above Oxford is about one-fifth of the total area above Kingston.

3110. Have you ever considered the question of a double supply, the one supply for drinking purposes and the other for other purposes?—I am not a water engineer, but I am of opinion that the complication of gas and water pipes and sewers in London is quite sufficient without introducing another set of pipes; but in the evidence upon the river Lea, Mr. Muir stated that the New River Company have power now to take and the means of pumping or abstracting water from the Thames for sewer flushing, surface cleansing, and similar uses, and by carrying out separate lines of mains they could supply it with great advantage for purposes of that kind, distinct from the domestic supply, which would relieve the volume taken from the Lea to a very great extent, and be a benefit to the metropolis.

The witness withdrew.

The witness subsequently forwarded to the Commission the following table:

TABLE showing the MONTHLY RAINFALL, from January 1855 to June 1866, at Cirencester and Kingston-upon-Thames, and the Monthly Average; also the Number of Days in each Month upon which a Rainfall was recorded at each of these Places.

Date.	Rainfall.			No. of Wet Days.	
	Cirencester.	Kingston.	Average.	Cirencester.	Kingston.
1855.	Inches.	Inches.	Inches.		
January	0·43	0·80	0·615	2	13
February	1·25	1·29	1·270	6	13
March	2·64	1·82	2·230	13	18
April	0·60	0·31	0·455	3	6
May	2·08	1·73	1·905	8	11
June	2·58	0·85	1·715	10	11
July	4·85	0·38	1·615	8	15
August	2·05	1·27	1·660	10	9
September	2·27	1·16	5·715	4	9
October	5·60	5·65	5·625	13	17
November	0·45	1·76	1·105	5	15
December	1·30	1·30	1·300	8	10
	26·10	24·32		90	147
Average	25·21				
1856.					
January	3·35	1·94	2·645	14	19
February	2·10	0 99	1·545	7	10
March	1·53	0 68	1·130	4	4
April	3·33	2·62	2·975	11	14
May	3·95	3·72	3·835	11	17
June	1·27	1·24	1·255	5	9
July	1·30	1·20	1·250	3	14
August	4·20	3·25	3·725	10	14
September	3·95	2·15	3·050	14	11
October	3·35	2·22	2·785	8	11
November	1·00	1·04	1·020	6	11
December	2·92	2·09	2·505	12	16
	32·30	23·14		105	150
Average	27·72				
1857.					
January	3·03	2·76	2·895	12	19
February	1·55	0·13	0·840	4	2
March	1·95	1·14	1·545	7	13
April	2·60	1·60	2·100	8	15
May	1·76	0·59	1·175	4	6
June	2·02	2·40	2·660	10	10
July	2·47	1·91	2·190	6	11
August	1·30	3·00	2·150	1	10
September	1·80	4 03	2·9 5	8	15
October	3·75	4·70	4·225	12	18
November	1·25	1·35	1·300	4	14
December	0·84	0·64	0·740	3	7
	25·32	24·25		79	140
Average	24·735				
1858.					
January	0·60	0·88	0·740	6	6
February	1·00	1·91	1·455	4	7
March	1·90	1·33	1·115	5	12
April	5·25	3·47	4·360	10	11
May	2·65	2·34	2·495	9	16
June	3·18	1·30	2·240	5	4
July	2·00	2·86	2·430	7	15
August	1·97	1·78	1·875	5	8
September	2·94	1·10	2·020	9	11
October	1·76	1·54	1·650	8	11
November	0·83	0·52	0·675	4	9
December	2·56	1·96	2·260	13	14
	25·64	20·99		85	124
Average	23·315				

Date.	Rainfall.			No. of Wet Days.	
	Cirencester.	Kingston.	Average.	Cirencester.	Kingston.
1859.	Inches.	Inches.	Inches.		
January	1·50	0·73	1·115	10	12
February	2·11	1·33	1·720	7	14
March	2·42	1·11	1·765	10	11
April	2·70	2·12	2·410	12	13
May	1·25	2·41	1·830	6	9
June	2·78	2·92	2·850	9	11
July	1·65	2·54	2·095	7	9
August	2·48	1·68	2·080	8	13
September	3·40	3·92	3·660	10	18
October	2·95	2·53	2·740	6	15
November	2·77	2·52	2·645	9	11
December	2·95	2·22	2·585	10	14
	28·96	26·03		104	150
Average	27·495				
1860.					
January	4·52	2·33	3·425	15	17
February	1·20	1·06	1·130	5	11
March	2·27	2·00	2·135	10	15
April	1·00	1·32	1·160	6	13
May	3·85	2·76	3·305	6	16
June	5·92	5·72	5·820	19	26
July	1·75	1·76	1·755	6	9
August	5·05	3·73	4·390	16	21
September	3·35	3·22	3·285	10	12
October	2·00	1·70	1·850	6	10
November	3·00	2·36	2·680	5	9
December	3·05	2·17	2·610	7	16
	36·96	30·13		111	175
Average	33·545				
1861.					
January	1·45	0·37	0·910	3	5
February	2·95	1·70	2·325	12	13
March	2·90	2·27	2·585	11	17
April	0·65	1·10	0·875	2	6
May	1·15	1·33	1·240	3	8
June	2·65	2·63	2·640	7	13
July	3·94	2·61	3·275	14	18
August	3·16	0·69	1·925	6	9
September	0·90	1·69	1·295	15	14
October	1·74	0·81	1·275	10	7
November	4·10	5·13	4·615	11	15
December	1·80	1·39	1·595	7	9
	27·39	21·72		101	134
Average	24·555				
1862.					
January	2·70	1·93	2·315	11	13
February	0·35	0·56	0·455	3	5
March	4·70	4·26	4·480	14	17
April	2·22	2·54	2·380	9	12
May	3·05	4·10	4·025	8	15
June	2·97	2·41	2·690	9	14
July	2·68	1·78	1·930	11	13
August	2·25	3·45	2·850	8	10
September	3·87	2·37	3·120	8	9
October	4·72	4·07	4·395	15	23
November	0·55	0·96	0·755	2	8
December	2·10	1·70	1·900	9	11
	32·46	30·13		107	150
Average	31·295				

J. T. Harrison, Esq.

9 May 1867.

TABLE showing the MONTHLY RAINFALL, &c.—*continued.*

Date.	Rainfall.			No. of Wet Days.	
	Cirencester.	Kingston.	Average.	Cirencester.	Kingston.
1863.	Inches.	Inches.	Inches.		
January - -	3·30	3·00	3·150	14	14
February - -	0·72	0·42	0·570	4	6
March - -	1·25	0·60	0·925	7	6
April - -	1·23	0·64	0·935	4	8
May - -	1·40	1·18	1·290	6	6
June - -	5·32	4·50	4·910	12	11
July - -	0·50	0·93	0·715	2	3
August - -	3·65	2·10	2·875	10	11
September -	3·00	4·50	3·750	12	15
October - -	3·75	2·13	2·940	15	17
November -	2·10	1·92	2·010	11	11
December - -	1·73	1·41	1·565	7	9
	27·95	23·32		104	117
Average -	25·635				
1864.					
January - -	1·82	0·89	1·355	10	8
February - -	1·93	1·04	1·485	5	9
March - -	3·08	3·15	3·115	9	12
April - -	1·40	1·06	1·230	6	7
May - -	1·50	2·05	1·775	7	10
June - -	1·35	1·40	1·375	10	13
July - -	0·88	0·34	0·610	5	6
August - -	1·24	1·60	1·420	4	6
September -	3·68	2·61	2·145	13	13
October - -	2·25	1·61	1·930	10	5
November -	3·30	3·01	3·155	10	11
December - -	2·25	0·33	1·290	5	6
	24·68	19·09		94	106
Average -	21·885				

Date.	Rainfall.			No. of Wet Days.	
	Cirencester.	Kingston.	Average.	Cirencester.	Kingston.
1865.	Inches.	Inches.	Inches.		
January - -	4.21	3·96	4·085	7	12
February - -	2·50	2·04	2·270	8	14
March - -	1·40	0·92	1·160	4	8
April - -	1·25	0·67	0·960	5	6
May - -	1·92	3·56	2·740	8	13
June - -	2·05	3·54	2·795	4	4
July - -	5·50	2·80	4·150	12	8
August - -	4·00	3·88	3·940	10	12
September -	0·08	0·35	0·215	1	2
October - -	6·46	6·45	6·455	16	20
November -	3·67	2·77	3·220	14	14
December - -	2·78	1·20	1·990	5	7
	35·82	32·14		94	120
Average -	33·98				
1866.					
January - -	4·13	3·73	3·930	19	20
February - -	4·04	4·87	4·455	13	17
March - -	1·40	1·74	1·570	10	12
April - -	2·15	1·98	2·065	10	14
May - -	0·73	2·34	1·535	2	8
June - -	4·15	3·80	3·975	14	11

SUMMARY.

Date.	Rainfall.			No. of Wet Days.	
	Cirencester.	Kingston.		Cirencester.	Kingston.
	Inches.	Inches.			
1855 - - - -	26·10	24·32	—	90	147
1856 - - - -	32·30	23·14	—	105	150
1857 - - - -	25·22	24·25	—	79	140
1858 - - - -	25·64	20·99	—	85	124
1859 - - - -	28·96	26·03	—	104	150
1860 - - - -	36·96	30·13	—	111	175
1861 - - - -	27·39	21·72	—	101	134
1862 - - - -	32·46	30·13	—	107	150
1863 - - - -	27·95	23·32	—	104	117
1864 - - - -	24·68	19·09	—	94	106
1865 - - - -	35·82	32·14	—	94	120
	323·48	275·26		1,074	1,513
Average - - -	29·40	25·00		97·6	137·4
	Average 27·2 over whole area.				

Dr. E. A. Parkes.

Dr. EDMUND A. PARKES examined.

3111. (*Chairman.*) Will you kindly state to the Commission the public appointment which you hold?—I am the Professor of Military Hygiene in the Army Medical School at Netley.

3112. Have you long held that appointment?—For the last seven years.

3113. Of course your attention has been directed to questions in relation to the health of the troops and the effect of water upon the health of the troops generally?—Yes.

3114. Can you give the Commission information as to any experiments which you have tried with regard to the use of comparatively pure water and waters of different degrees of hardness, or soft water, where you have had the means of testing the effect of soft water and hard water upon the health of the troops?—I have got a good deal of evidence together as to diseases which may be communicated by water, not only to the troops but among the civil population. I have made a list of diseases, all of which are occasionally communicated by means of water, not solely communicated by water but occasionally. For example, typhoid fevers; of which I have collected about 23 instances of local outbreaks of severe typhoid fever, and some six or eight more, the particulars of which I have not got, are known to me arising from water impregnated with typhoid sewage, or possibly with simple sewage.

3115. When you speak of typhoid sewage do you mean sewage from persons suffering from typhoid fever?—Yes.

3116. Can you detect that after its mixture with the water?—Not by any chemical re-agents.

3117. But under the microscope have you the means of detecting it?—No, there is no possibility of determining the particular substance which causes the fever in other persons. We only know the effect produced upon other persons, and no doubt it is from that cause.

3118. How did you ascertain that those outbreaks were due to water impregnated with typhoid sewage?—On account of the cases immediately following that impregnation with typhoid sewage. I do not wish to deny that simple sewage might produce the same disease, but that is a question still undecided.

3119. Have you the means of tracing the discharge of that class of sewage into the water, and the results following in fever?—Yes.

3120. Have you obtained many confirmatory results from that observation?—There have been altogether a considerable number of cases now placed upon record by different writers of such an effect following the passing of typhoid sewage, or possibly of simple sewage into drinking water. We had a case in the neighbourhood of Southampton only this last year, in a young lady's school, where a drain pipe passed within three feet of the well; at the point nearest the well the soft ground below the drain pipe had given way, and the pipe had sunk, and the sewage passed into the water of the well. Immediately following that was an outbreak of typhoid fever which affected something like 80 per cent. of the population, that is to say, 18 or 19 persons were affected out of a

population of 24 or 26 ; there were several deaths, and many of them very severe cases. In that case it was impossible to prove whether or not it had been typhoid sewage passing into the well ; but the impregnation of the water with sewage was certain and coincident at that time, and that, coupled with several cases of the same kind, seem to show that the outbreak of the fever is owing to the impregnation of the water with sewage.

3121. Would not the discharge of sew ge into any water which was the source of supply for domestic purposes favour the development of such zymotic diseases. I am not speaking now of typhoid fever sewage only, but of ordinary sewage ?—That is the general belief certainly ; there may be still a little doubt whether that is really the case. For example, in the instance of cholera, it was formerly believed by most medical men that the impregnation of drinking water with sewage would predispose to cholera at any rate ; but during the last year in Germany there have been a good many instances recorded in which very impure water had been drank during the whole period of the cholera epidemic without apparently producing any predisposition to cholera, I mean water impregnated with common sewage, not choleraic sewage ; the inference rather being at present that choleraic sewage must pass into the water to produce cholera. So that I should hardly like to express an opinion too positively as to the effect of sewage predisposing to zymotic diseases.

3122. Supposing that the condition of the atmosphere is favourable to the development of cholera, and that in addition to that the patients take to drink water polluted by sewage, would not that have a tendency to develope it with great rapidity ?—I should certainly think so, and that is the general belief, and it may be probably true.

3123. As far as your special observation has gone, in all cases where there has been a discharge of human excreta into water where the parties have been suffering from typhoid fever, that has generated disease in every district where the water has been taken for domestic purposes ?—It has not generated typhoid fever in all cases, because in some cases it has generated diarrhœa and dysentery ; typhoid fever has prevailed in some cases and not in others, and therefore that is an argument in favour of the view that it requires the typhoid sewage especially to pass into the water for the development of that particular fever, and that simple sewage will not cause it. But the question is surrounded with difficulties ; it is so difficult to get reliable scientific evidence that it is still *sub judice*.

3124. Have you had any means of forming a judgment as to the value of hard water as compared with soft water for drinking purposes ?—With regard to the effect upon health of the use of hard waters, distinguishing between the carbonate of lime water and the sulphate of lime, and sulphate of magnesian waters, the carbonate of lime waters appear in some cases certainly to produce some effect upon health ; for instance, dyspepsia, and they do not agree with some class of persons, whereas to others they appear to be quite harmless. There is a large population living upon chalk water, and we cannot trace any very decided effect upon their health in the production of any class of disease—calculus or anything of that kind, but at the same time persons do sometimes suffer from indigestion.

3125. What degree of hardness would, in your judgment, be a safe water, taking an average constitution ; some people will live in spite of difficulties ; their resistive force being such that nothing seems to effect them, but my question has reference to an average constitution ?—I do not think with regard to pure chalk water that there is any evidence that a moderate amount of carbonate of lime in the water does any harm, certainly not on the large scale ; in some individuals it produces indigestion.

3126. Would 16 or 20 degrees of hardness be prejudicial ?—I think that that degree of hardness would be certainly prejudicial. I think that very probably it might disagree with a great many persons ; but supposing it reached to 8 or 10 or 12 degrees of hardness from carbonate of lime, it might be considered probably good water as far as that was concerned, but I should draw a marked distinction between that and the hardness arising from sulphate of lime or sulphate of magnesia or chloride of calcium, which would certainly disagree in much smaller quantities, so that the goodness of water for drinking purposes I would estimate according to its permanent hardness rather than according to its temporary hardness.

3127. Are you acquainted with the waters that are supplied to the metropolis by the several water companies ?—Yes, I know them very well.

3128. Take the Southwark and Vauxhall Company for example, the total hardness of their water is 17·7 ? —Yes, but I do not know how much of that is permanent. The table of Dr. Frankland does not enable me to see how much is permanent. The total hardness merely is put down, and the other ingredients that are stated do not allow me to tell how much of that is permanent, but I suppose that it would be four or five degrees.

3129. (*Col. Harness.*) How do you distinguish between permanent and temporary hardness ?—Simply by boiling ; permanent hardness is that which remains after boiling. Supposing we have a water containing carbonate of lime, sulphate of lime, and magnesian salts, the hardness after boiling will consist of a certain portion of carbonate of lime, two grains per gallon held in solution, and the remainder of the hardness arises from the sulphate of lime, the sulphate of magnesia, and the chloride of calcium. That we call permanent hardness which we cannot break down by boiling, and that water certainly is worse than the carbonate of lime waters, which lose a great part of their hardness by boiling. Consequently, many persons living on carbonate of lime waters, for instance at Chatham and such places, take comparatively but little carbonate of lime, because they take the water in tea, and lose a great deal of the carbonate of lime ; even after standing the water loses a great deal of the carbonate of lime, so that in tea they would take it tolerably free from carbonate of lime ; that would be different from water of permanent hardness.

3130. (*Chairman.*) Have you had an opportunity of witnessing the effect of different waters upon the troops when moved from one station to another ?—I have seen reports upon that subject. I am stationary myself, and I have not made any observations upon that point.

3131. Can you give the result of the experiments of changing troops from one water to another ?—At present in the army they take a great deal of care with the supply of water ; the water is constantly examined, and pure water only is issued to the troops.

3132. When you say "pure water," do you mean soft water ?—I mean water especially which is free from organic matters ; whether it would be soft or not would depend upon the district, but water which does not contain any decided impurity of any kind, and the greatest care is taken at present, so that with regard to the army serving at home the influence of bad water is almost perfectly excluded. Now and then instances occur in which wells become impregnated, but the water is always examined by the medical officer, and any suspicious water is laid aside, so that it is almost impossible now to bring any evidence of disease amongst the troops arising from water.

3133. We may assume of course that any organic impurity would be objectionable in water, especially sewage ?—Yes.

3134. But supposing the water was equal in purity and free from organic matter, does the question of simple hardness or softness enter into the consideration of those whose special duty it is to care for the troops with regard to the kind of water that they should use ?—In all cases we would prefer a soft water if it were possible to obtain it ; and if the water were permanently hard, to a large extent that water

Dr. E. A. Parkes.

9 May 1867.

would be reported upon unfavourably, and better water as regards that property would be procured if it were possible.

3135. Do they resort to any means of softening the water where they are unable to obtain soft water?—In one instance it is done, at the Herbert Hospital at Woolwich where they employ Clark's process to soften the water. In that case it is carbonate of lime water and it is softened to some extent before it is distributed in the hospital. I believe that that is the only instance in the army.

3136. (*Col. Harness.*) Did they do anything with the Chatham water?—No, the Chatham water is very pure chalk water containing scarcely a trace of sulphate of lime, but a large quantity of carbonate of lime, 16 or 17 grains.

3137. (*Chairman.*) Speaking generally, you are of opinion that the mere presence of carbonate of lime or 15 degrees of hardness would not be injurious to health?—With 15 or 16 degrees of carbonate of lime hardness I should say that it would be hard water, and with some persons it would disagree and produce dyspepsia. I think it should not exceed 10 or 12 degrees if possible. At the same time I should wish to state that one would prefer water free from that even, if it were possible to get it.

3138. For all other sanitary purposes I presume there can be no question that soft water would be preferable?—No question at all.

3139. Has your attention been directed to the means of storing water in vessels of slate, or lead, or iron?—To some extent, but it has been on a small scale.

3140. What is the effect of soft water on lead?—It dissolves it in considerable quantities, particularly if the water contains much oxygen.

3141. Is that effect continuous or only at first?—I believe it is continuous.

3142. Is it not found that when lead becomes coated the absorption does not go on after a certain time?—The chalk waters deposit largely on lead, and some of the other lime waters also, but the soft waters continually take up lead, so that the pipes and cisterns are eaten through with soft water. We have many instances of that in our neighbourhood, where we have soft water, and the use of lead has been entirely discontinued, so rapidly has the water eaten through the lead; and iron pipes are corroded by soft water more rapidly than by hard water, because they become corroded like lead pipes. It is a matter of great consideration with regard to the supply of water to London that although lead pipes are almost universally used they have now become nearly harmless by being coated over by the deposits from the hard water, and it would become very hazardous if means were not taken to secure the pipes against the action of soft water.

3143. Are you acquainted with the mode which is adopted by several of the water companies for the purpose of filtering their water?—I know most of the plans which are in use I think.

3144. Do you think that the system of filtration which is adopted is likely to prove beneficial except in removing that which is held in mechanical suspension?—I believe it does not do much if anything more than that, it merely removes mechanically the substances floating in the water to some extent, not in all cases.

3145. That which is held in solution will pass through unaffected?—Yes, nothing will take out substances in solution I believe unless the filtration be conducted with other substances than those commonly employed on a large scale, unless they employ animal charcoal especially.

3146. But the mere rough sand filtration would simply have a tendency to free the water from mechanical impurities had in suspension?—Quite so.

3147. In the paper you have been good enough to send to the Commission you state that the purest and most wholesome water should contain no suspended matters, and that the amount of dissolved organic matters in it should be under one grain per gallon, and of dissolved mineral matters under seven grains per gallon?—In my minute of the evidence that I proposed to give I attempted merely to form a sort of standard which might be understood by the public as to what waters were best. It seems desirable to give the public some sort of idea what waters may be used or what may not be. There are difficulties in forming a standard which may not be objected to by scientific men on account of the difficulty of making the evidence very precise upon such a point as this, and therefore such an enumeration of waters as I proposed must be received merely as an attempt, without pretending to anything like scientific accuracy; but I think that the following standard of water will convey the most important points connected with the supply of drinking water. I would propose to form a class of "wholesome waters," under which two sub-classes of waters may be included, first, the purest and most wholesome water which is free from suspended matters, and contains very little dissolved organic matters, say under one grain per gallon, and that probably vegetable, and of dissolved mineral matters under seven grains per gallon. That will include all the best waters supplied from the primitive rocks, and from some of the sands which contain under that quantity of mineral matter, and is probably the purest water on the whole which can be obtained in that way.

3148. How would that compare with the Loch Katrine water?—It would include the Loch Katrine water, which contains under one grain of organic matter per gallon, and two or three or four grains of mineral per gallon. It will also include the water of some of the sands, such as the Bagshot sands, which contain under seven grains per gallon, which may be put in the same class. The Loch Katrine water is the purest and most wholesome water which can be obtained in that way, and rain-water after filtration might come under the same standard. Then the second sub-class in the first order would be what I would call pure and wholesome water to which no objection can be taken, I believe, in a sanitary point of view, but which is not so pure as the former. This water is also free from suspended matters, having dissolved organic matter under two grains per gallon, the greater part of that being vegetable. Of dissolved mineral matters it would contain under 12 grains per gallon, consisting principally of carbonate of lime, and alkaline carbonates, and chlorides. That second sub-class would include the best chalk waters, which are often very free indeed from organic matter. Then the second grand class I would make, I would propose to call "usable waters;" waters which cannot, perhaps, be very much objected to, not so good as the former class, but yet which in many cases might be used, and which would not produce, perhaps, any bad effects. Those are all waters with no suspended matters or suspended matters easily separated by the coarse filtration usually resorted to by the water companies. The organic water would be chiefly vegetable, but it should not exceed three grains per gallon, owing to the diseases which would probably arise if it exceeded that quantity, and if the organic matter is apparently of a mineral origin it ought not to exceed two grains per gallon. Then it should contain mineral salts not exceeding 20 to 30 grains per gallon, and consisting of a class of salts which do no injury to the system, such as alkaline carbonates, alkaline chlorides, chloride of sodium, and chloride of potassium, in less quantity, and possibly a little carbonate of lime also.

3149. In all those three classes when you speak of organic matter you exclude sewage in any and every form?—Yes, I would exclude sewage throughout. The third class would be what I would call "suspicious water," which would be any water with much suspended in all which would be separated readily by matter filtration. Such a water as that would coarse probability contain either fine particles of mineral matters, which are hurtful, such as clay, or possibly it might contain

suspended organic matters very finely divided, and not very readily separable by filtration. It might contain dissolved organic matters, vegetable and animal, amounting to about three or four grains per gallon, and mineral matters of large amount, such as alkaline and chlorides, carbonates, and carbonate of lime in large amount, that is to say, perhaps over 9 or 10 grains per gallon, or sulphate of lime or magnesia, and chloride of calcium or magnesium in certain quantities; all those I should consider make a water suspicious; or if it contains any indication of nitrites, nitrates, ammonia, &c., showing that organic matters had passed into the water and had there been oxidized; any indications of that kind I should consider would bring the class under the head of suspicious water. Then the fourth class would be "impure water," which would include any turbid and bad smelling water with suspended matters not easily separated by coarse filtration; also dissolved organic matters above four grains per gallon, especially if of animal origin, large quantities of mineral substances, especially of sulphate of lime and sulphate and chloride of calcium and magnesium, which all give permanent hardness to the water, or large indications of nitrites, nitrates, fatty acids, ammonia, &c., all of which indicate the passage of organic matters, animal in all probability, into the water. To sum up I would propose as a popular division these classes.

1. Pure and wholesome waters.
2. Useable waters.
3. Suspicious waters.
4. Impure waters.

The definition of each would be as above stated.

3150. (*Col. Harness.*) Under which of those heads would you put the London water?—I should put the London water under head No. 3, suspicious.

3151. Would you do that because there are indications of nitrates?—Yes; I should call any water containing large indications of nitrates and nitrites suspicious water. Such indications may, however, come from water not impregnated with sewage, as some soils give off nitrates and nitrites.

3152. (*Chairman.*) Is the result of the Board of Health analyses of the London water sufficient to enable you to judge of its character?—As far as regards nitrates and nitrites and ammonia are concerned, it is quite sufficient to enable one to judge.

3153. Should you call it suspicious water?—Yes. I should certainly call it suspicious water.

3154. Which is the first of the London waters in Professor Frankland's analysis?—The first water is the Chelsea water, which contains nearly 28 grains of solid matter.

3155. Would you call that suspicious or impure?—I should call it certainly suspicious water. It contains nitrates, nitrites, and ammonia in some quantity, and knowing that such substances exist only in small quantities in pure Thames water I conclude they are derived from sewage.

3156. Will you be good enough to add to that statement under which denomination you would place the water, whether suspicious or impure?—Suspicious.

3157. (*Mr. Harrison.*) Allow me to call your attention to this report of Dr. Frankland's, in which, referring to this particular table of the analysis of the waters, he says, "By gradual oxidation partly in the "pores of the soil, partly in the Thames or its "tributaries, and partly in the reservoirs, filters, and "conduits of the Chelsea company, this sewage con- "tamination had been converted into comparatively "innocuous inorganic compounds before its delivery "to consumers." That has reference distinctly to this analysis in the weekly return of the Registrar-General; you, perhaps, could hardly say whether you would confirm that view of Dr. Frankland's or not?—I think that the mere presence of nitrates and nitrites in water in small quantities would not be hurtful at all; their importance is as indicating their source and showing that there must have been contamination, probably by animal organic matter, in most cases sewage, and of course rendering the chances of such organic matter passing in in sufficient quantities to affect the health very probable, but when such organic maiter has been oxidised, then no doubt it becomes, at any rate in most cases, harmless.

3158. (*Mr. Prestwich.*) Would it not be very difficult to distinguish the origin of the nitrates and nitrites, whether arising from sewage or from the rain, or from the earth, or from vegetation?—From the rain the quantity would be small; indications of nitrites will be found in rain water and in water from the earth, and there is a certain amount of difficulty in determining from what source they come. In our neighbourhood, for example, there is a sort of dark soil under the sand at certain points which contains very large quantities of nitrites and nitrates not derived at all from sewage, and the water drawn from those strata gives indications which might be taken in the first instance for sewage. That mistake could only be avoided by knowing the soils which furnish the water. In the case of the London water, the Thames water, which is furnished in such large quantities from the chalk, will, I believe, in no case without sewage contamination, give large indications of nitrites and nitrates; there would not therefore be any difficulty in supposing that the indication of nitrites and nitrates would be owing to organic matter which had found its way into the water from the sewage, still there would be a difficulty in all cases in saying at once that the presence of nitrites and nitrates in water was owing to sewage matter or any other accidental organic matter.

3159. In the case, for example, of forest lands, even at a distance from towns, have not instances been known of water flowing from such forest lands containing quantities of nitrites and nitrates?—I have no doubt of it; in fact, there is scarcely any water in which some small quantity of nitrates does not exist.

3160. (*Chairman.*) Sewage is the most dangerous parent of those things, is it not?—Yes. But any indication of them should lead at once to an examination, so as to trace the origin of nitrates and nitrites, and the water would be suspicious in the proportion that it contained any large quantity.

3161. (*Mr. Prestwich.*) It would not be a certain inference that it was from sewage?—Certainly not.

3162. (*Chairman.*) Your attention, I think, has been directed to the question of a constant or an intermittent supply of water, and its advantages or disadvantages. Will you favour the Commission with your views on that subject?—There are great sanitary advantages in a constant supply, namely, in doing away entirely with the house storage. The house storage entails a great chance of the water being impure, either from the cisterns being allowed to get filthy or from substances finding their way in from the overflow pipes communicating with sewers and drains, and gases forcing their way back through imperfect traps. All these evils the constant supply entirely does away with, but the disadvantages of the constant supply are certainly the very great quantity of water that is wasted, and the occasional failure at times when it is very important indeed to have a large supply of water. For example, last year, in Southampton, in the time of the cholera, when it was extremely important to have the drains well flushed, and everything carried out, we had rather a failure in the supply of water in the low parts of the town. The population in the higher part of the town being nearer the reservoir used a very large quantity of water owing to the dryness of the season, also their gardens required a large quantity of water, and this was taken from their constant supply. At the same time there happened to be also some alterations going on in the pipes and in the machinery, which also lessened the quantity. The consequence was that we were unable in the low parts of the town for several days during the prevalence of the cholera to ensure a proper quantity of water passing through to the sewers.

3163. That would be rather an accident when the

Dr. E. A. Parkes.

9 May 1867.

works were out of gear and would not affect the general principle of constant supply?—No doubt, but at the same time there is always a danger of an insufficient supply at times. There is scarcely any town that can ensure a supply so large as to enable it to meet all the demands of a large population.

3164. For example, supposing a town had a reservoir in a convenient place, giving a sufficient head to distribute the water all over the town, within a short distance, with 21 days supply stored, or with a capacity to store 21 days supply, would you be in doubt as to the efficiency of the constant supply as compared with the intermittent supply?—It would be necessary to know what in that case you would take to be the daily supply per head of the population.

3165. Assume, for example, 40 gallons per head for manufacturing and all other purposes?—Then of course it would depend upon the size of the town.

3166. Assuming a population of but 5,000 or 20,000, you would have a supply equivalent to that which would be distributed under the intermittent system and stored in the houses, but you would have it placed at every man's house, so that he could take it as he required it?—I believe that the system of constant supply is by far the best if you can do away with the principal chance of failure by apportioning out large towns into smaller ones and having the constant supply only applicable to a certain number of houses by a particular set of pipes, that is to say, by having numerous reservoirs which would be equivalent to supply say 5,000 or 10,000 people, so that at any time you may be quite certain that you have not only got a supply for that particular district, but that it cannot fail in consequence of an increased demand which may be made by other districts upon a single reservoir.

3167. (*Chairman.*) Your fear would be as to the capacity of the public or public company to supply the whole district in a case of emergency such as occurred at Southampton?—Quite so, in the case of any large town. In the case of a small town I conceive that there would be no difficulty in the supply.

3168. Assuming that you have an ample supply for the whole population of a town, are you of opinion that the system of constant supply for all sanitary purposes is infinitely superior to that of an intermittent supply?—Quite so, if you can get over the practical difficulties and the enormous waste, but I think that if you have the coustant supply it must be understood that there is to be no stint in the water in any part of the district at any time as there appears to be in some towns which are supplied with the constant service.

3169. When you speak of the seeds of disease being conveyed in water, would boiling have any effect upon that water, so as to destroy the germ which conveys from one patient to another choleraic or any other disease?—Exact experiments upon such a point as that are impossible. You cannot make any experiments as to whether or not water would convey it after boiling; you can only estimate it by chemical agencies. The effect of boiling is not very much to destroy organic matter in water; it may destroy some, but it does not destroy a great deal. Boiling, *per se*, is not such a purifier of water as is sometimes supposed. It throws down a great deal of suspended matter; it throws down carbonate of lime if it exists in the water, which carries down also suspended matter; but dissolved organic matter is not much destroyed by boiling.

3170. But the question is whether by subjecting this germ of disease to heat for a certain period its vitality would be destroyed?—I could give no answer to that, because I do not think that any experiments could ever be made upon such a point. It could only be done by a series of observations of people, with respect to people drinking the water who had boiled it and people drinking it who had not boiled it. With regard to cholera and typhoid fever no observations have been made as to the effect of boiling destroying the germs of disease.

3171. There has been an experiment recently made by a French professor, with regard to the seed of a plant which was boiled for four hours and which yet retained its vitality?—It is almost impossible to say; speaking in a true scientific spirit, namely, from evidence, whether boiling would or would not destroy the cholera or typhoid germ in water.

3172. You know of no means by which water of a suspicious character could be deprived of those injurious compounds?—It can be very readily deprived by filtration of organic matter, and I presume of those compounds also, but I have no evidence that water which would produce cholera in one person when subjected to proper filtration would not produce cholera in another. I think it is very likely that it would not, but of course such an experiment as that cannot be made, but filtration through animal charcoal and through many filters now in the market (and there are four or five admirable filters in the market) will take out a great quantity of animal matter from the water. For example, I have with me a confidential report made to the War Office of some experiments of my own which I have made upon the chief filters in the market. I find that some of them will remove of organic matter (sewage matter that is to say) from water, as much as 95 per cent. and that others remove 89 per cent. and others 83 per cent.

3173. In the case of the 95 per cent. is that a charcoal filter?—It is a charcoal filter. It is not one of the common charcoal filters. The worst filter that I could get which might be considered a filter at all, and which was a charcoal filter, removed 69 per cent. of organic matter from the water, so that a very considerable effect is produced upon water by proper filtration on a small scale; and it is to be presumed that it is scarcely possible that any organic substance carrying a germ of disease could escape through such a filter; but in the absence of experiments, I would not undertake to say that it would not.

3174. Then the mere boiling of water would add little to its safety?—I do not think that it would add much. I have made a few experiments upon that point, and I was able to detect some organic matter after boiling. Suspended organic matter is thrown down certainly.

3175. (*Col. Harness.*) You assume that the seed of disease, whatever it is, remains in the organic matter?—I cannot conceive that mineral matters of any kind produce such diseases as typhoid fever or cholera.

3176. Might not something which is not organic matter affect the water so as to make the water unwholesome, although it is not separable from the organic matter in the water?—Then it would be some substance which is not dead organic matter but live organic matter. It must be something which I should class under the head of organic matter.

3177. (*Chairman.*) Is there in your judgment an objection to the Thames basin as a gathering area for water by reason of the high state of cultivation in some parts, and from the manuring that it undergoes?—Yes, I think there is a very great objection. No doubt the effect of water passing through a soil with manure is to cause a very rapid oxidation of the organic matter, and a very large quantity is converted into nitrates, and nitrites, and ammonia, but there is a limit to that, and it is impossible to insure the safety of water where there is the possibility of contamination on a large scale with organic matters derived from sewage.

3178. If it passed through a sufficient depth of earth it would be deprived, would it not, of this matter?—The earth would be a great purifier, no doubt.

3179. But if the soil is saturated at the time the manure is placed upon it, and a sudden fall of rain should follow to wash it off without its passing through that strong deodorizing soil, it would carry with it a great deal of objectionable matter?—Yes, there is constant danger in that respect.

3180. You have observed of course the inherent

power of water to purify itself by exposure to the atmosphere?—Yes.

3181. Have you observed in a case where sewage has been discharged into a river that after running for three or four miles the effect of that sewage has been destroyed?—Yes, we have that in the case of the Southampton water supply; some sewage passes into the Itchen river, but it is quite destroyed by the time the water is distributed in Southampton, at least there is no detectible quantity.

3182. What is the distance?—The distance is six or eight miles. I could not undertake to say the distance in which water would purify itself in that way, but there is no doubt that it does purify itself, although in what distance or what time or under what precise circumstances I could not say.

3183. I presume that the sewage probably by the action of the water and the atmosphere would really be broken up into other elements of a less injurious character?—Yes, broken up into compounds of nitrogen and ammonia, nitrates and nitrites.

3184. You do not get rid of it, you have it in a different form?—Yes.

3185. And in a less objectionable form?—Yes, in a form I presume quite unobjectionable in a small quantity. A very large quantity might be irritant, but in a case in which they would be in water not very largely impregnated with sewage I should think that they would not be hurtful.

3186. Do you think, taking the upper part of the Thames as a gathering area, that any injurious result from manuring or other washings into the river would by the course of such water down the Thames be somewhat neutralized?—I think that very likely it would be neutralized to a very considerable extent. That would rather depend upon the amount passing in; if any experiments could be made as to the amount of manuring and the number of acres that would furnish sewage matter, and the amount of sewage matter which would pass in, and the rapidity of the flow of the Thames at different parts of the year, and the volume at different times in the year, we should be able to form a better idea. It would be modified by a great many circumstances.

3187. But there would in your judgment be a process of purification going on?—Yes, it would be simply a question of degree.

3188. Dependent upon the quantity of pollution in the volume of water?—Yes. On that point it might be possible to make experiments. The only real answer for such a question would be the experiments made as to time and distance and the amount of oxidation which would go on under various circumstances connected with the lower waters of the Thames.

3189. If water is soft when it is taken into a culvert either at the head of the Severn or in the lake district, are you aware whether in its transmission to the metropolis through tunnel or open cutting, any chemical change would take place in that water with regard to its quality?—In the flow of water changes do take place if the water is exposed to the air. For the most part the chalk waters deposit some portion of their carbonate of lime. On the other hand, in passing through pipes of any kind, the nature of the pipes might possibly furnish substances to the water.

3189. They take up iron, do they not, for example?—Yes, most waters would do so till the iron had got covered with a deposit.

3190. (*Mr. Prestwich.*) In speaking of those diseases produced by the impurities of water in cases in your experience were they well water, or river water, or spring water?—If you will allow me I will enumerate the various diseases which have been traced to the impurities of water. Dysentery has been traced in a good many cases to the effect of water, both river water and occasionally well water, and diarrhœa in the same way. Many rivers, particularly those loaded with suspended matters or containing a quantity of sewage matter, have produced dysentery and diarrhœa. Many of the American rivers, and some of the Russian rivers, the Volga for example, are loaded with sewage, and the water of the Nile in certain cases produces dysentery.

3191. (*Chairman.*) When you speak of that effect of the Nile water, does it arise from the large amount of vegetable matter in the water?—No, the Nile water is very pure above Cairo, but lower down it becomes impregnated with sewage. At certain times of the year the quantity of water in the Nile is small, and then it produces diarrhœa and dysentery.

3192. Is not there a large amount of decomposed vegetable matter in the Nile?—Yes, no doubt there is some, but in some specimens of the Nile water the vegetable matter is very small. No doubt at different times of the year it would vary in that respect. To resume the statement of the diseases, cholera is produced occasionally by water, not always, but the choleraic poison is carried in water, and marsh and malarious fevers also.

3193. Do you concur in the view entertained by Dr. Farr and others with regard to the cholera water so called, of a kind of milky colour which is observable in the water at certain elevation?—I do not think I am quite aware of the point.

3194. There is a diagram showing the effect of elevation upon the spread of cholera and how that peculiar cholera germ is suspended at a certain elevation and how the disease developes itself at a certain height; have you seen that diagram?—I am not acquainted with it. I know his observations on the effect of elevation on the spread of cholera, but that is apart altogether from any question of drinking water.

3195. (*Mr. Prestwich.*) You stated, did you not, that the river for example at Southampton had received the sewage of towns above the source of supply to Southampton?—Yes, sewage applied to the land.

3196. Not town sewage?—I believe that it does receive some of the town sewage of Winchester.

3197. But by the time it reaches the reservoir at Southampton the water is so oxidised that it becomes comparatively pure?—Yes.

3198. Therefore your observation with regard to the spread of disease from water from wells and rivers applies, I presume, to cases where there is a decided impregnation at the spot?—Yes.

3199. And where the flow has not been sufficient to produce the oxidation?—Quite so.

3200. Can you give any instances of the effect of water upon the health of the troops arising not from sewage contamination or organic contamination but from a change in the character of the water in its mineral constituents?—There are various stations where the water is not particularly good, and where it has produced an effect upon the health of the troops; for instance, at Gibraltar the well water is very impure, and the troops have been obliged to be removed.

3201. The greater part of the troops I presume in this country are located in districts where the water is of a moderate degree of hardness; for instance, Dover, Portsmouth, Southampton, Plymouth, and the greater part of Ireland?—Yes, and at Chatham. At Southampton we have no troops, and at Aldershott, the troops are upon soft water. At Chichester the water is hard and at Colchester it is hard. For the most part they are chalk waters.

3202. Have you known instances of any ill effects from the use of such waters?—Not of the good chalk waters.

3203. Have you known any instances where troops have been located in districts where they have been using water of a moderate degree of hardness, and have suffered when they have been removed to a district where the water was soft?—I have never seen any reports of that kind.

3204. Are there troops located at Aberdeen?—There is only a small number at Aberdeen except when the Queen is in the Highlands.

3205. You have no means of knowing the effects of the use of such waters?—No.

Dr. E. A. Parkes.

9 May 1867.

3206. (*Col. Harness.*) The removal from Chatham to Manchester would be a good test, have you known any instance of that?—No, but I could make inquiries. If any medical officer had reported that the health of his soldiers had been at all injured by transference from water of one kind to water of another kind, I think it would have been reported, but I can make inquiries upon that point, and add it to my evidence.

3207. (*Mr. Prestwich.*) You have mentioned the case of Woolwich where they use Clark's process for softening water, does not that arise from the circumstance that the waters there are unusually hard, and are derived from wells, the water of which is of a greater degree of hardness than is furnished by the waters in the chalk districts?—Yes, it is hard water, and the water having to be supplied to the hospital, and it being considered of importance to have pure water for the patients; I believe that that was the chief consideration which led to the use of that process, but the water is very hard which is derived from the wells there.

3208. Should you not consider that streams flowing through a chalk district such as the Downs, where they would be free from all sewage contamination, would be perfectly pure and good waters?—Yes; I have made a great many inquiries upon that point, and I believe that when it is a chalk water within certain limits, it is a harmless water, at least I have never been able to trace any ill effect upon health. But occasionally chalk furnishes bad water; for example, at Chatham, some of the wells there furnish very unwholesome water, containing a considerable quantity of sulphate of lime; therefore it does not follow that in every portion of a chalk district the water supplied by the soil would be a pure chalk water. In some of the well water at Chatham we have a large quantity of sulphate of lime, and even of magnesia, and in some cases indeed there is the presence of iron in considerable quantities.

3209. The tendency in waters furnished from the chalk districts is to part in a certain proportion with their lime, that is to say, water from wells from a chalk district would be of a much greater degree of hardness than water from a river flowing through the same district?—Yes, a river drawing its water from the chalk and having any length of flow would certainly part in the course of that flow with a considerable quantity of its hardness.

3210. Therefore the waters in the wells would be considerably harder than the waters in the rivers in the same districts?—Yes.

3211. With regard to the action of hard waters in taking up organic matters, could you give us any opinion with regard to the facilities of solution which such waters may have?—No, I have found large quantities of organic matters in all kinds of water. Some waters very free from mineral matters would take up organic matters very readily, and chalk waters and other lime waters will take up organic matters. I have not been led to suppose that there has been any difference in their degree of solvability of sewage matter.

3212. Are you aware whether a certain quantity of carbonate of lime may not in many cases be rather beneficial than otherwise to health?—I think that is again very doubtful. The fact is, that almost all kinds of food contain enough lime for the supply of the body, and the quantity of carbonate of lime supplied in water might no doubt be applied to the wants of the system, but I can hardly think that it would be necessary, that is to say, I do not think it should be an argument for the supply of chalk water that lime is thereby supplied.

3213. Some of the authorities both in this country and in France have been of opinion, have they not, that the presence of lime was rather beneficial than otherwise?—Yes, several have been of that opinion, but some of the chief arguments have been derived from the feeding of pigs, for example, by a French chemist, and it has been shown that his calculations have hardly borne that idea out. He supposed that the lime supplied in the water was really applied in the nutrition of the pig, but it was shown that enough lime was passing in the food to give all the lime that was really wanted.

3214. Provided it was not kept upon some particular food in which a certain quantity of lime was present?—Quite so.

3215. But apart from the use of lime for the formation of bone, I presume that the presence of lime as a slight alkali is combined with the carbonic acid in the water. Do you attach any importance to that?—I should not attach any importance one way or the other perhaps to it. There are certain persons who are not able to take carbonate of lime water from its producing in them constipation and dyspepsia, but they are a small minority.

3216. And that would hardly arise in the case of a population which has been accustomed to the use of such water?—I should think not.

3217. I see that one disorder which you mention is calculi; have you been able to trace that back to the use of water?—In Germany especially there is a very strong opinion in certain parts that the phosphate of lime calculi and calculi generally are more common in districts where the inhabitants use very hard waters, but in this country the evidence is so far negative; we have not many districts supplied with limestone waters or the magnesian limestone waters; most of our lime waters are chalk waters, and so far, I think, in this country there is no evidence of there being a greater amount of calculi than in other districts not supplied with this water, but in Germany and, perhaps, in France the evidence is stronger that the use of some of the lime waters may have an influence in the production of some of the calculi.

3218. Would that be in the case of water of an ordinary degree of hardness, or of an excessive degree of hardness arising from the chalk or from the presence of sulphates?—I believe especially from the large amount of hardness arising in most cases from the mixture of chalk and of sulphates, at least it is so in most of those waters.

3219. You mentioned, did you not, one disadvantage of the constant supply at Southampton, namely, that there were times when the supply was short?—Yes, that was the case last year, and that was in part owing to a temporary defect in the machinery, and they lessened the supply on that account; but, I believe, in other towns where they have the constant system, there have been difficulties in the supply from time to time.

3220. Do you know what the quantity of storage is at Southampton?—I could not tell that without reference, it is very considerable.

3221. Have you had opportunities of determining the quantity of water which it would be desirable to furnish to the troops per head?—That will entirely depend upon the way in which the sewage is disposed of.

3222. For all purposes I mean?—Including the washing away of sewage, and all purposes connected with washing, and the houses, and everything else, I generally estimate it at about 25 gallons per head per diem.

3223. (*Chairman.*) You think that that would be sufficient for all purposes?—Yes, for all purposes, I think, in this country.

3224. I suppose troops use a larger proportion of water than the ordinary population per head?—I am not aware that they do. There is a great deal of washing, but whenever they get plenty of water there is a good deal of washing going on.

3225. (*Col. Harness.*) Would that quantity include water constantly supplied to the latrines?—Yes.

3226. But you do not know in what proportion it includes it?—I believe, about from 8 to 10 gallons per head, and the remainder is water which is used for washing, cooking, and other purposes. At the same time I should say a much less quantity is used at some stations than that.

3227. Have you ever been at a station where the water was so scarce that it was obliged to be taken care of, such as it would be at Bermuda for instance?—No.

3228. (*Mr. Harrison.*) Taking generally the Thames basin, there is nothing in it that occurs to you as objectionable for general purposes in any water that would be obtained in that basin, assuming it to be free from sewage?—I am not aware that there is. At certain times of the year there is a little clay washed down, which makes it a little turbid, which is sometimes not very readily separated by filtration, but beyond that, supposing you consider the carbonate of lime in it unobjectionable, I do not see that there is anything in the water of the Thames, as far as health goes, which is objectionable.

3229. The water of which you have got an analysis in the table before you is water into which the sewage of many large towns, containing altogether a population of nearly 1,000,000 inhabitants, is now passed into the Thames direct?—Yes.

3230. Assuming that under the powers of the Act of last session all that sewage will be diverted in the first instance from the Thames and used upon land, would you not consider that the result would be that it would be very much purified beyond what it is at the present moment?—I have no doubt of that at all, but it is impossible to say what the amount of purification would be, because I do not know what the conditions would be of the irrigation of land in proximity to the river, or the amount of water which would pass through the land.

3231. All that would be laid upon the chalk and oolites would be almost entirely absorbed by the land, would it not?—Yes.

3232. But where the sewage is laid upon the clay it would come off more rapidly?—Yes.

3233. Do you think that if that plan were carried out there would be still an impurity in that water sufficient for you to say that it ought not to be used?—I should feel very great difficulty in answering that question.

3234. You seem to say now that from Dr. Frankland's analysis it is what you would call a suspicious water?—I should say so, because there has been certainly organic matter in it derived from sewage, and though that has been oxidized to a considerable extent, still, as showing previous impregnation, and as indicating that there might be a further passage of sewage into the water, and the possibility of a less degree of oxidation at certain times, I should call it a suspicious water.

3235. Then until that purification has taken place which is now in progress, and the water is analysed afterwards, you think that no opinion could be formed upon that point?—I should like to know whether it would be effectual or not in completely diverting the sewage from the Thames, and I should hardly think it possible to form any opinion upon that point.

3236. (*Col. Harness.*) Supposing that the sewage of Chatham was employed upon the meadows and gardens in the valley of the Medway, how would that affect the water supplied by a large well in the chalk?—It would be a dangerous experiment; it takes some time to penetrate through chalk, but we know it is penetrated. Some of the large wells in the lower part of Rochester are separated by a considerable distance of chalk, but they have become penetrated, and of course a constant supply of sewage upon the surface in the immediate vicinity of that well would be dangerous. The danger in the chalk, as in the sand, is in a channel being worn, and finally a considerable passage taking place into the well.

3237. (*Mr. Harrison.*) Do you think that in point of health the population of London generally suffer from any impurity in the existing water apart from any special case of cholera in the east of London?—I think that where the population of every town shows a considerable amount of diarrhœa and also of typhoid fever it makes one believe that there must be some impurity in the water at times, and the health of the population as regards those diseases of the intestines seems to be very much influenced by the purity or impurity of its water supply.

3238. If you had the choice you would prefer to go to such water as you could procure at a large expense, such as the Loch Katrine water?—Yes, if one had the opportunity, of course.

3239. Could you give any measure at all of the difference of value as regards the question of health between the two, that is to say, as between using such waters as are now used in London, and using such waters, if they could be got, as those of Loch Katrine?—I am quite certain that the health of the people would be improved considerably, but I could not give any numerical standard. I believe that most diarrhœa affections would disappear, and typhoid fevers would be diminished, and that the chances of cholera being conveyed by water would be almost entirely taken away. I can hardly conceive that there would be any chance of any conveyance of cholera by water.

3240. (*Col. Harness.*) Have you made any comparison as to the continuance of those diseases between two places where the waters were very different—between where the water was soft and where it was hard?—Not in large districts. People suffer from drinking impure water in either case from diarrhœa certainly. There has been some very valuable evidence given as to the effect of the change of water on dysenteric affections in Bermuda and the West Indies. Those diseases which used to be very prevalent there, and which were owing to the water, have disappeared almost entirely. At the present time in Jamaica, where there used to be so much dysentery, there is far less than there is at Gibraltar or in Malta, or in the Mauritius, and other stations of that kind.

3241. What has been the change in Jamaica?—The change has been the supply of good water, chiefly rain water. In many stations in the West Indies rain water is used, and in many places the carbonate or sulphate of lime well or river water has been entirely given up, and the effect has been a marvellous alteration in the health of the troops. I believe that that is the cause also now in Barbadoes and Trinadad. The improvement of the water has been followed by the disappearance of certain diseases.

3242. In the West Indies they have introduced the softest possible water?—Yes, wherever they could obtain it, either by springs or by rain water.

3243. (*Mr. Prestwich.*) Is there not almost a total absence of evidence with regard to the effect upon health of the use of such water as comes from the primary rock and from the calcareous districts apart from all question of the contamination of towns or sewage?—If in the expression calcareous you mean the carbonate limestone, or chalk, it is extremely difficult to get evidence upon that point at present. Our attention has been so little turned to the effects of water of that kind that I can hardly give you any evidence which would be satisfactory as showing that the inhabitants of primitive districts enjoy a better state of health than those supplied with pure chalk water, but at the same time the general bearing of all evidence is to show that the purer the water which is supplied to the system the better it is for the processes of the body, but I may say that that is only a sort of impression derived from the general study of disease and health, but it is almost impossible to bring forward statistical evidence as to the presence of disease here as compared with disease in another place which would be convincing.

3244. It is said that the inhabitants of mountain districts, for example, either Wales, or Switzerland, or Scotland, enjoy a better state of health than the inhabitants of a limestone district, such as that of the central part of Ireland. Have you any information on that point?—Our difficulty is in making all the circumstances equal. There is not only the question of food, but there is the concentration of the inhabitants, and the occupation and everything else has to be considered in addition to the water, and that

Dr. E. A. Parkes.

9 May 1867.

makes the comparison so extremely complicated that it is very difficult to give a decided opinion.

3245. (*Mr. Harrison.*) If the subject had been considered one of vital importance by the medical profession generally, do not you think it would have been proposed that it should be scientifically investigated by some specially appointed body either of medical men or chemists?—We must remember with regard to the effect of different things upon the health of the community in this country that it has only been the subject of investigation for the last 30 years. Till we began to have statistics of deaths we had not learnt to know the relative prevalence of the several forms of disease, and it was impossible to form any opinion as to the condition under which the people were living. We may say that these questions are almost in their infancy.

3246. Is it not your idea that it is an important question for scientific investigation?—I think it is a very important one, and I am certain that many diseases are communicated by the agency of water, and I consider that the effect of pure water on health is of the very highest importance; but if you ask me for evidence to give chapter and verse for everything, I should find a difficulty in doing so.

3247. Assuming that it were practicable to supply London with a water equal to that of Loch Katrine, supplementing the present supply, would not it be exceedingly difficult to arrive at any conclusion as to what it was worth upon any information which is possessed at the present moment?—At the present moment it would. I do not thiuk you could get any statistical evidence, and even after you supplied it there would be a difficulty of course in proving the case, because you cannot prevent other sanitary improvements going on at the same time, improvements in drainage and improvements in other things which might affect the health of the community.

3248. Would not the question be in a great measure governed by the opinion of medical men as to there being anything decidedly wrong in the present water supply, and in order to justify a complete change of the present system, should it not be based upon some decided evidence of defect in the present supply?—But at the present time the supply in London is known by chemical evidence to be impure, apart from any statistical evidence of disease.

3249. (*Col. Harness.*) Would you object to a site for a hospital where the water to be obtained was of the quality of the London water?—I should certainly say that the London water has been impregnated with sewage from the evidence of the oxidation of nitrogen, and therefore, being impregnated with sewage, I should think that there would be considerable danger in the use of it.

3250. (*Mr. Harrison.*) Allow me to point out to you the last paragraph in the last report from the Registrar General's office; do you agree in the opinion that that water is innocuous?—I understand that a quantity of sewage was poured in, and it was then oxidised and converted into simple compounds before the delivery of the water.

3251. It is simply by the process which it passes through in the river, and this being an analysis after it had passed through that process, the opinion is there expressed that it is innocuous, would you be of the same opinion?—I should think that it would be innocuous if it were completely converted into those compounds, the nitrates and nitrites of ammonia, if the quantity of sewage was not large in the first instance.

3252. That is the condition which is there reported as being that of the London water in the month of April last?—Yes, the sewage has been already converted, but then there is a constant danger that it will not be so converted. Those salts show previous contamination and a possible future contamination, therefore it is not that they themselves may be hurtful, but they show that matters which may be hurtful have passed in and may pass in again, and you cannot rely always upon the sewage matter being thus converted.

3253. (*Col. Harness.*) Do they not also, to a certain extent, lead you to infer what the remaining organic matter is, and may it not be of the same kind unconverted?—Yes, but I understand here that all the organic matter has been converted from day to day, and it might chance that one day it might be entirely converted and the next day not be entirely converted.

3254. (*Mr. Harrison.*) That appears to be only the result of a single day's experiment, the analysis of a particular day?—Yes.

3255. Still that is a report from Dr. Frankland, who is at the head of that department?—Precisely so.

Adjourned to Thursday next, at 11 o'clock.

Thursday, 16th May 1867.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND, K.G., IN THE CHAIR.

Sir JOHN THWAITES.
Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

N. Beardmore, Esq.

16 May 1867.

NATHANIEL BEARDMORE, Esq., examined.

3255. (*Chairman.*) You are a civil engineer, are you not?—Yes, I am a member of the Institute of Civil Engineers, and have had a good deal to do with water matters from my earliest youth. I have studied them as a matter of science as well as a matter of practical professional engagement.

3256. (*Mr. Harrison.*) You have also published a book which is well known as Mr. Beardmore's Tables on Hydraulics?—Yes, I published a book called "Tables" some years ago, then I published a more complete thing afterwards, and I hope to publish something better by and by; these things grow on. The object of that book was to give as much information as could be given on subjects similar to that which the Commission is now inquiring into.

3257. (*Chairman.*) Are you acquainted with the schemes and propositions that we have had before us for bringing water from the lake district, and also from Wales to London?—I am generally acquainted with them, but not in detail. I may say at once that they are matters much too large for me at all events to be able to judge. The works would be too heavy, and the nature of waterworks requiring you to pick the level, to a great extent renders it much more difficult to judge them than you would of a railway works where you can get a gradient a little steeper, and modify your works accordingly.

3258. Are you acquainted with the present sources of water supply to the metropolis?—Very well acquainted with them.

3259. Are you sufficiently well acquainted to be able to give a very confident opinion upon that subject?—Yes, I know a good deal about it, and could give a very fair opinion, so far as I am able, on the present sources.

3260. You are acquainted, are you not, with the Thames basin?—Yes, I am acquainted with the Thames basin, and also the river Lea basin. Perhaps I may be allowed to state that about 18 years since I became connected with the trustees of the river Lea, from whence, at that time, a supply of two-thirds of London was taken. There was then a great demand for an increase of water, and the quantity which the two companies drawing water from the Lea could take was very much limited. Owing to mills and other rights they had been very much checked. At that time they had been looked upon as taking, as it were, a little drop out of the Lea by favour, but in the course of years arrangements were made by which finally the whole of the valley practically was sold to the two companies. I felt then, what I have expressed with regard to the Welsh scheme, that really we were very much in the dark as to the volume of water that those streams gave. It is true Mr. Telford, and then Mr. Rennie, had gauges taken of the Lea once or twice, but it was evident that the volume of water was perpetually changing, and I established a system of gauging the river from day to day, and now I have carried it on 18 years, and by carefully observing and collating the facts, and comparing other basins with it, and particularly the basin of the Thames, I am able to give you a tolerably near approximation to what the flow of the Thames is, and I am able to predict pretty well what it would be under the driest or the wettest state of the year.

3261. (*Sir J. Thwaites.*) I thought you stated that your observations applied to the river Lea and not to the Thames?—I have gauged the Thames occasionally to test it by the Lea, and they are both very similar districts in some respects; they have a very similar rainfall.

3262. At what point did you make your gaugings on the Thames?—I have gauged the Thames at various points, at Kingston, at Staines, at Maidenhead, and different points.

3263. Did you make a careful section of the river?—I have taken it by velocities, and sometimes by the weirs in different ways.

3264. Is it a safe test to take the weirs?—A very safe test for the time being, for what you can get it at the moment. It is no test of what the river is running by the year; but you can get a very fair test for the time, and in gauging I have been also in the habit of taking it by the sections and by the velocities. There is no weir upon the Thames where you can take a day by day gauging, but I think Mr. Thornhill Harrison has laid down Mr. Simpson's height of the Thames at Kingston for a series of years, and I think he has got a very fair approximation to the flow from that, but still none of them are perfect; there is no perfect gauging of the Thames, over continuous periods.

3265. None of the weirs I think are in such a condition as really to permit of an accurate gauging being made?—No; I was very anxious some 13 years ago to get Mr. Bazalgette to begin to do so and he came out with me, but it was not practicable. Mr. Leach, the present engineer of the Upper Thames Conservancy, will I hope make one or two gauging-weirs. I have advised the Commissioners in the new works to make a weir somewhere up near Oxford and down below at Bell Weir, near Staines, and so to arrange these weirs that they can be gauged; my idea is that it may be well to put in the "Times" newspaper every week what the Thames is flowing. I could publish the volume of the Lee every week if I chose.

3266. Have you any tables to put in as evidence of the result of your gauging, or would you state it generally to the Commission?—I can put in a table which I have prepared showing the flow of the Lea and the estimated flow of the Thames for 18 years. I have lately prepared it, and I believe it to be very nearly correct.

The witness delivered in the following table:

Estimated Flow of Rivers Lea and Thames.

Mean Annual Flow, 1850 to 1866, including the Water Companies Supply.

	River Lea at Feilde's Weir. Drainage area, 420 square miles.				River Thames at Kingston. Drainage area, 3,670 square miles.				
Years.	Discharge per minute.	Discharge in gallons per day.	Depth run off.	Rainfall at Feilde's Weir.	Discharge per minute.	Discharge in gallons per day.	Depth run off.	Rainfall at Oxford.	Rainfall at Cirencester
	Cubic Feet.	Millions.	Inches.	Inches.	Cubic Feet.	Millions.	Inches.	Inches.	Inches.
1850	10,464	93·9	5·64	22·22	125,568	1,126·8	7·74	24·2	—
1851	11,800	105·9	6·36	21·90	129,800	1,164·9	8·00	22·0	—
1852	17,892	160·6	9·64	39·50	178,920	1,606·0	11·06	40·4	—
1853	21,762	195·3	11·72	28·75	217,620	1,953·0	12·41	27·2	—
1854	10,335	92·7	5·57	17·85	93,015	834·3	5·73	17·7	—
1855	9,404	84·4	5·06	25·01	94,040	844·0	5·81	25·2	26·10
1856	10,698	95·0	5·78	23·90	128,376	1,140·0	7·91	27·0	32·30
1857	11,942	107·1	6·43	25·36	119,420	1,071·0	7·36	27·5	25·22
1858	8,615	77·3	4·64	20·86	94,765	850·3	5·84	22·5	25·64
1859	7,818	70·1	4·21	29·24	78,180	701·0	4·82	27·0	28·96
1860	18,462	165·6	9·90	33·75	184,620	1,656·0	11·41	31·1	36·96
1861	14,091	126·4	7·60	20·94	169,092	1,516·8	10·42	23·4	27·39
1862	11,629	104·3	6·26	25·75	139,548	1,251·6	8·60	27·41	32·46
1863	8,594	77·1	4·60	21·97	103,128	925·2	6·37	22·37	27·95
1864	6,811	61·1	3·68	17·88	74,921	672·1	4·63	18·26	24·68
1865	9,768	87·6	5·26	28·79	107,448	963·6	6·62	28·53	35·82
1866	15,480	138·9	8·34	32·25	154,800	1,389·0	9·54	30·67	37·93
Means -	12,092	108·4	6·50	25·64	129,015	1,156·6	7·90	26·02	30·12

N. Beardmore, Esq.

16 May 1867.

ESTIMATED FLOW of RIVERS LEA and THAMES—*continued.*

Years.	River Lea at Feilde's Well. Drainage area, 420 square miles. Discharge per minute.	Discharge in gallons per day.	Depth run off.	Rainfall at Feilde's Weir.	River Thames at Kingston. Drainage area, 3,670 square miles. Discharge per minute.	Discharge in gallons per day.	Depth run off.	Rainfall at Oxford.	Rainfall at Cirencester.
Mean Flow for June, July, August, and September 1850 to 1866.									
	Cubic Feet.	Millions.	Inches.	Inches.	Cubic Feet.	Millions.	Inches.	Inches.	Inches.
1850	7,753	69·5	1·40	7·30	77,530	695·0	1·59	9·9	—
1851	7,346	65·9	1·36	7·40	66,114	593·1	1·36	8·3	—
1852	9,944	89·2	1·79	13·60	99,440	892·0	2·18	17·5	—
1853	14,438	129·5	2·59	10·90	144,380	1,295·0	2·97	11·4	—
1854	6,663	59·5	1·20	4·70	59,697	535·0	1·23	5·1	—
1855	5,476	49·1	·99	10·30	54,760	441·9	1·11	11·6	11·75
1856	6,839	61·3	1·23	8·20	68,390	613·0	1·40	10·6	10·72
1857	6,512	58·4	1·17	9·00	58,608	525·6	1·20	12·5	8·49
1858	6,279	56·3	1·13	8·00	62,790	563·0	1·22	8·5	10·09
1859	5,009	44·9	·90	12·31	45,081	404·1	·93	12·3	10·31
1860	17,789	159·6	3·20	14·35	160,101	1,436·4	3·30	13·8	16·05
1861	9,139	82·2	1·65	5·30	91,390	822·0	1·81	10·7	10·65
1862	8,550	76·7	1·54	7·77	85,550	767·0	1·76	7·89	12·17
1863	5,684	51·0	1·02	9·62	56,840	510·0	1·17	9·44	12·47
1864	4,744	42·5	·85	5·73	42,696	382·5	·88	5·21	7·15
1865	4,812	43·1	·87	9·11	43,308	387·9	·89	9·60	11·63
1866	8,386	75·2	1·51	11·75	83,860	752·0	1·74	13·83	17·87
	7,960	71·4	1·45	9·14	76,502	683·3	1·57	10·48	11·61
Mean Flow for June, July, August, and September in the driest Years, 1855, 1859, 1864, 1865.									
1855	5,476	49·1	·99	10·3	49,284	441·9	1·11	11·6	11·75
1859	5,009	44·9	·90	8·2	45,081	404·1	·93	12·3	10·31
1864	4,744	42·5	·85	9·0	42,687	382·5	·88	5·21	7·15
1865	4,812	43·1	·87	8·0	43,308	387·9	·89	9·60	11·63
	5,010	44·9	·90	8·9	45,090	404·1	·95	9·68	10·21

3267. (*Col. Harness.*) Can you show it relatively with the rainfall of the same periods?—Of course I have put upon the table the rainfall of the same periods, but we are rather at a loss with regard to the Thames for a true estimate of the rainfall, just as you are at the head of the Severn, from what I understand. It is a very curious thing that there are no records of rainfall at the proper head of the Thames; that is to say, on the hills round at the back of Swindon and Cirencester, and so on, for a series of years; but I have had lately given me by Mr. Harrison the record of a rain gauge kept at Cirencester, and it shows what one might have predicted, that there is very considerably more rainfall at the head of the Thames than there is at Oxford. Oxford I believe, generally speaking, among those studying the subject, has been the standard: the rainfall is registered at the Radcliffe observatory.

3268. Does the height at that point offer a large face to the west?—No. The rainfall at Cirencester is not such as you would speak of with regard to mountains; it merely has some two or three or four inches a year more rain than Oxford, but this increase is a very important element in the perennial flow of a river like the Thames. During the last three months we have had decidedly heavier rains on the hills at the head of the Thames; these get into the oolite and give a very valuable flow of water during the time when it is important that the Thames should be full; that is to say, in the hot weather. If you have a good full spring rain, it is the character of all those rivers from chalk and oolite to give good volume through every kind of weather to the end of August, and that is a very important point to be considered.

3269. (*Chairman.*) Have you been able at all to determine what quantity of water could be supplied to London from the Thames basin, setting on one side the question of pollution, and speaking of it merely as to quantity over and above what is obtained at present?—The whole volume of water in the Thames during the minimum month of dry years may be taken at about 380,000,000 gallons per diem above Kingston—that is quite the minimum.

3270. (*Sir J. Thwaites.*) Is that for any given year, or is it the average?—The mean of the four months of June, July, August, and September, for 1864 and 1865, was only a little above 380,000,000 gallons per diem.

3271. What was the minimum?—The absolute minimum I do not know, but I should say it was not much lower than that. Those years were extremely dry years, according to my calculations. I have no year at all so low as those two years; 1854 should have been a low year, but there was an enormous volume of water the year before, and therefore the Thames flowed during the summer a very fair volume; 1855 fell down as low during the four months as 490,000,000 gallons, but it would have been lower had it not been for the immense supply of the year 1853; 1864, being a very dry year, had also the not high year of 1863 before it, and therefore the water fell off; 1863 was not at all a wet year, therefore 1864, being a very dry year, was low, and the drought ran into 1865.

3272. Has your observation enabled you to determine how many months of storing capacity those districts of chalk and other formations possess; that is to say, how many months is necessary to exhaust the storing capacity of that district?—That is just the point which I was going to answer. I have been searching for a law applicable to that for a very long time, and it is only within these last three weeks that I thought I had discovered this decided law; viz., that if you have a year of very low rainfall, with a hot summer, the chalk springs will gradually fail, and if there should be no October rains it will fall down almost to a minimum in November, but the absolute minimum is felt in the September of the following year, so that the storing power of the chalk is at least 16 months, because July is almost always a full month with chalk springs; for instance, the minimum in 1864 was only reached on the Lea in the September of that year, but the absolute minimum came in September 1865. In every dry year that we have had September has been the minimum month of that year, but the absolute minimum of the flow has been the September following. And the way in which it acts is this: The springs are running a constant and diminishing volume, because the rain of the year before and

the winter before has not been sufficient to replenish them; they are, therefore, absolutely diminishing. Then when you have got to the September of a dry year the winter rains following have not time to get down to the lower beds of the chalk, and although they have an effect in increasing the land springs, and keep the volume of the river up during the winter, and even during the summer months, yet the draining out of the lower springs developes itself at least in the September following a dry year. That is a rule; at least it is so nearly the rule that it has happened three times in 18 years on the river Lea.

3273. Then what makes you sceptical as to the correctness of that rule?—I am not sceptical, except merely that I am sceptical about anything with regard to rainfall and volume without even a longer series of years than we have had.

3274. You stated just now that you thought that you had discovered an unerring law with regard to the rainfall, the absorbing power of the chalk, and the time that that chalk would be discharging that which it had absorbed; have any circumstances led you to doubt the correctness of that law?—Nothing has led me to doubt it. It is only when I get an immense mass of figures collated before me that I can discover it; I feel perfectly confident about it. We had a general impression upon the Lea Valley that it was so some time ago, but I had not got the proof of it.

3275. (*Mr. Prestwich.*) Those deductions you draw from your observations on the Lea?—Yes.

3276. Where the conditions were very favourable, having a basin of only one geological formation?—Yes.

3277. Where in the Lea Valley were your observations taken?—At Broxbourne, at the junction of the Stort, and by gauging the flow off an area of 420 square miles.

3278. (*Sir J. Thwaites.*) Can you state when this chalk and other formations have discharged all the water, how many months or how many inches of rain would be necessary to re-fill that basin?—That I cannot tell except by inference, because after about a week's heavy rain in October the land springs and the upper chalk springs begin to fill and you get a mixture of the water; you get a large volume and it is impossible to tell the difference.

3279. But the water which would find its way to the lower bed of chalk would begin to flow would it not?—That we cannot tell, because we cannot gauge any one chalk spring, we only know that in dry years the higher chalk springs in the valley cease to flow, and that the lower springs do not vary in their volume to anything approaching the same extent.

3280. But you know the outlets from the various levels, and if they are all found running you have a right, have you not, to assume that the basin is pretty full all the way up?—Yes, perhaps after the October rains the upper chalk springs will begin to flow again. There is a very large spring at Woolmer park, for instance, that falls off in a dry year, and after about a month's heavy rain it begins to flow again very copiously.

3281. Can you state to the Commission the average rainfall within the Thames basin?—The average rainfall in the Oxford part of the Thames basin from 1850 to 1866 is 26·02 inches in the paper which I will put in, but I do not think that that is the average rainfall of the district. Oxford is only about 180 feet above the sea and a great many of the Thames hills are from 300 to 400 feet, and there is a most decided increase of rainfall as you get up.

3282. (*Mr. Harrison.*) What would you calculate rainfall at, taking the average of the Thames basin?—I doubt that as a whole, considering its more easterly position, any more rain falls in the Thames valley east of the parallel of Oxford than 26 inches. In some parts about Cobham there is decidedly less than 26 inches, but west of that parallel I should think that there are from three to four inches more rainfall, taking it over the whole surface.

3283. (*Sir J. Thwaites.*) Have you calculated the amount of rainfall in the area and compared it with your gaugings of the quantity of water flowing down the Thames in any period, so as to ascertain how many inches of rainfall actually flows off?—I have calculated it, and you will see that on this table I calculated that on the average of years about 8 inches flow off the Thames; but in the year 1859 there was only about 4·82 flowed off, and in 1864 there was only about 4·63 flowed off.

3284. Was 1858 a dry year?—Yes, but according to my calculations 1859 had the lowest flow. It may be interesting to know that the mean volume for this year is about 700,000,000 gallons flowing down the Thames at Kingston; the mean flow of 1858 I compute to have been about 850,000,000 gallons per diem.

3285. How do you account for the very small result of 4 inches for example in 1858 and 8 inches in the other years during an average rainfall of 26 inches. How do you get rid of the remainder; is it by evaporation, or by what?—By evaporation and absorption.

3286. That which is absorbed would naturally flow off, would it not?—No, it evaporates.

3287. If it be absorbed it would not evaporate?—It would be absorbed into plants. What I call flowing off is combining the whole of what goes into the surface and so into the chalk and into the springs, and absorption and evaporation in that sense is what the plants take up and what evaporates. There is an enormous quantity taken up by grass and plants during this time of the year. We know it practically because the first inch of rain in October after an ordinary dry year gives no water at all. Those valleys take no notice of the first inch of rain; it all goes into the thirsty plants and the soil.

3288. You have 26 inches to account for; that seems a very large amount of rainfall, does it not?—It is 26 inches if you reckon the average of years.

3289. (*Mr. Harrison.*) In a particularly dry season the reservoirs in the chalk become to a great extent exhausted, then they require to be filled again, and they are filled again; that would take in itself in that particular year a very large quantity of rainfall that year if it comes when the reservoirs have been exhausted?—Quite so, and I think I may say that in all those cases nature provides for herself. If you have a tremendously hot summer the ground cracks and thunderstorms come and the rain goes right into those deep cracks and replenishes the springs at once; I am clearly of that opinion. In 1864 I saw that practically myself. Cracks were formed all over the country; the first rains went right into them and they really were not lost; nature replenishes herself in that way. I think that, perhaps, part of the theory of springs, particularly in hot countries, is that the rain goes right into the cracks and fills them up; it is by this process that springs in India or such countries as Judea are fed, where the ground is baked and you have practically only four months rain. Of course the four months rain would have run away altogether if it were not that those cracks take the fall of rain and so feed the lower springs.

3290. (*Sir J. Thwaites.*) Of course your attention has been directed to the plan proposed by Mr. Bateman and also that proposed by Messrs. Hemans and Hassard. With regard to the rainfall to be obtained from the area described by Mr. Bateman, have you seen his calculation?—Yes.

3291. Do you concur in the net result which Mr. Bateman anticipates from that area?—With the little knowledge that I have of the matter I should exercise a sound prudence in declining to give an opinion, excepting in this way. The opinion that I am going to give has been given when I knew much less of these things. As much as 18 years ago I expressed the opinion to a very eminent engineer that I am now going to give. There is no amount of rainfall which, in a course of years, may not be exceeded, and, in this climate, there is hardly any amount of drought that may not be exceeded also, and I feel certain that no storing scheme is absolutely perfect. The area

N. Beardmore, Esq.

16 May 1867.

should be very large if it has to supply a large quantity of water, because you cannot, in this climate, avoid a couple of dry years coming together.

3292. Are you of opinion that the the mean rainfall would be a hazardous basis for a scheme of this kind?—Certainly, in the way it is applied, it is no basis on which to judge. If you wish for a real conclusion, you must gauge the streams, and keep rain gauges all over the country for some years.

3293. Assuming that the rainfall in the district has been thoroughly gauged, and that you have, therefore, no doubt as to the amount of rainfall, would you take the minimum rainfall as the basis of your calculation, or the mean?—Decidedly not the mean; but taking the minimum must be a little governed by the facts; for instance, if you had a very large amount of reservoirs, and had one very dry year, such as I am told occurs in those places sometimes, if you happened to have in the November previous a heavy rainfall, although the previous year may not be a very heavy year, you may catch enough to tide you over an absolute minimum year. It must be a matter of gauging the streams, and of calculations from those gaugings, as compared with the rainfall; but applying the general knowledge of these subjects which one has, I should say that you must not apply the figures of the rainfall in districts with a westerly aspect, or at the head of valleys trending towards the sea on the west, to ascertain the probable rainfall on easterly slopes. It is true that a very large amount of rain does go over some mountain summits, but, as a general rule, mountains are an absolute bar to the progress of the rain towards the interior. That is to be seen at Bombay in a very marked manner. A man could walk in a day from a district of 100 inches of rain into a district of 18. In the Himalayah mountains there is no doubt that the western face has an immense rainfall, but the interior of Thibet has none at all, or scarcely any; and those laws prevail in the small mountains and hills even in these districts of moderate rainfall.

3294. Assuming that careful gaugings have been taken for 20 years, and, taking the minimum fall during those 20 years, do you think that that would be a sound basis for the calculation and arrangement of a general scheme of water supply, giving of course, as every prudent engineer would, increased capacity to his reservoirs and all his works to meet cases of contingency?—Yes, if you rely upon the minimum falling over any given district. Perhaps a better instance cannot be quoted than the Liverpool case. In the year before last there was a scarcity of water there, and no one denies that the district is not a most prolific source of water, but they suffered there from drought. It has been said that they suffered from want of store reservoirs, but, in my opinion, it is quite a mistake; they suffered from one of those periodic droughts.

3295. But they did not take the minimum fall in that case, they took the mean of three dry years for the size of the reservoirs?—Yes, not the mean rainfall of these years, otherwise it would have required more than three or four times the amount of reservoir.

3296. (*Chairman.*) To go back to Kingston, and the daily flow there, which you say is 380,000,000 gallons, how much of that is now taken by the existing companies?—About 50,000,000.

3297. That leaves about 300,000,000 as the minimum going down the Thames?—It would leave the present minimum surplus falling over Teddington about 330,000,000, but the river is supplemented afterwards to the extent of some 60,000,000 to 80,000,000 between that point and Vauxhall Bridge.

3298. (*Sir J. Thwaites.*) Above the point where the water supply is taken there is no increase, is there, to the 380,000,000?—No, but after the water companies have taken their supply the Thames is again supplemented.

3299. With reference to Mr. Bateman's plan, and the gathering ground, you have stated that you have not sufficiently examined it to give a confident opinion as to the amount of water that may find its way into the several rivers?—No, I think I could not judge of that without keeping gauges and gauging the streams.

3300. And would you give the same answer with regard to Mr. Hemans's scheme for taking water from the Lake district?—I have not looked into Mr. Hemans's scheme sufficiently to give an answer, excepting generally that there is no doubt, I think, that the Lake district is more fertile of rain than the head of the Severn; taking area for area there is more water from the Lake district than from the Severn, unless you could get out to the western flank of Plynlimmon and Cader Idris; the amount of water that falls on the western face of those mountains is immense.

3301. But there would be an engineering difficulty about that?—Yes.

3302. Speaking as an engineer generally upon this question, and apart from the question of cost, are you of opinion that a sufficient supply of pure water to London might be obtained from the source pointed out by Mr. Bateman or by Mr. Hemans? I am not asking you as to the expediency, or as to the cost, but whether, as an engineer, you are prepared to state that a sufficient supply for the metropolis, present and future, could be obtained from either the one source or the other, say up to 300,000,000 gallons?—I should say that it is impracticable, having regard to the expense of the works.

3303. Do you mean by impracticable that the water could not be collected and stored, or do you mean that they could not construct the works to convey it to the metropolis?—I mean that to convey 300,000,000 gallons to the metropolis, to collect it, to store it, and to be sure of having the water, would be a very doubtful matter in its effect upon the quality of the water, and the expense would be so great that it would be beyond the means of any company; 300,000,000 gallons is a very large quantity to carry.

3304. What sized river would be necessary, in order to give a fall of 12 inches to the mile?—I understand, from Mr. Bateman's statement, that he reckons on a river 30 feet wide and 10 feet deep.

3305. But that is not with a 12-inch fall?—No, you cannot work a 12-inch fall. It would just be like what was the case in the Ganges canal, where there was a failure in carrying the water, from their fancying that they could work that amount of fall. You must not let water in that volume go along at such a speed. It is true that you may want a fall of a foot per mile, because you may and will have to pass wide valleys and ravines, which it would be beyond the power of man to cross in any other way than by pipes.

3306. You think that any fall beyond 6 inches would tear up the canal?—Yes. Practically you could not work even at 6 inches. You would require to have sluices at intervals for maintaining the level of the water. An average fall of a foot per mile I think is a very fair estimate, because you would concentrate your fall at places where you would have to put pipes across the ravines; I have no hesitation in saying that it would be quite impracticable to carry out any scheme without passing the valleys by pipes.

3307. With proper precaution is there any engineering difficulty in bringing 300,000,000 gallons of water to London?—No engineering difficulty beyond the cost. If you could insure rock tunnels all the way as they have at Glasgow you could race down the water at a velocity which should be quite a foot in a mile.

3308. But they have not rock tunnel all the way at Glasgow?—They have got a very large quantity of rock tunnel at Glasgow, and they can lead the water away with a very small aperture, but you could not do it through a great portion of the proposed district. You must make a canal which should carry the water along at a reasonable rate, and consequently you must have a larger canal with a smaller fall.

3309. What do you think would be a safe fall in a canal constructed as a canal of that description would be, lined with rubble or concrete?—I should think a

maximum of 6 inches, but I should be quite disposed to take credit for a foot to help me over difficulties. In many places in laying out the line you would require to have direct drops in your level.

3310. Of course, if you diminish your fall you must increase the size of your channel?—Yes, and as a matter of convenience and economy, I think it would be desirable to do so. You must not let 300,000,000 gallons of water get the master of you.

3311. (*Col. Harness.*) What velocity of current do you think would be allowable with a lined channel?—I think generally you must reckon it at two miles an hour, say between a mile and a quarter and two miles an hour. I think it would practically work out to that.

3312. (*Mr. Harrison.*) You have given a good deal of attention to the river Lea of which you are the engineer. Is the quantity supplied from that basin now nearly all taken up by the water companies?—In the year 1864 and September 1865 the river Lea volume was reached, but I must state that they had practically very little reservoir. The Lea must be treated with the reservoir system, and if you want a very largely increased volume down the Thames it must be the same.

3313. Supposing that additional reservoirs were made in the Lea, could the actual quantity now taken from the Lea by the water companies be much enlarged?—The minimum quantity taken by the companies is somewhat under 40,000,000 gallons, and the minimum flow of September 1864 and 1865 was somewhere about the same; and reservoirs, within practicable and reasonable limits of expense, can be made so as to store the winter spring water and deliver about 70,000,000 gallons.

3314. You think that the Lea itself would be capable of increasing the present supply from 40,000,000 up to 70,000,000 gallons?—From 40,000,000 gallons, as the minimum, up to 70,000,000 gallons; but there are many years when the river Lea gives 70,000,000 gallons right through the year. In fact, the river Lea, out of 18 years, in 1859 dropped to a mean of 70,000,000 gallons, and in 1864 it dropped to a mean of 61,000,000 gallons; but we could do a great deal more than 70,000,000 gallons on the Lea if the water from the Lea districts were supplemented from the Thames during very exceptional periods, because, generally speaking, our volume is up to about 90,000,000 gallons. We could give 90,000,000 gallons per diem throughout the year from the Lea valley as a general rule, with the aid of reservoirs.

3315. Taking now the basin of the Thames, you have stated that 380,000,000 gallons is the average of dry seasons over three months above Kingston, do you know whether the quantity at Teddington lock has ever been as low per day as 305,000,000 gallons accurately gauged?—No; I gauged it myself in July 1864, and Mr. Simpson gauged it off and on for a month in the same year, and we make it the same figure almost.

3316. What is that figure?—380,000,000. I have not got anything below.

3317. Is that at Kingston?—At Teddington.

3318. But do you take it above or below the water supply?—Whatever I speak of includes what the companies take.

3319. I am referring to that which is left after the water companies have taken their supply?—I think it is possible it may fall to 305,000,000 gallons on exceptional occasions, because at the time the gaugings were made the companies might have been pumping hard, or taking in an extra quantity for the next day.

3320. Or the mills may have been using the water?—Yes, in the dry time, in the upper district, every miller shuts in the water, particularly on Sunday. I should say that Tuesdays or Wednesdays water at Teddington, in very dry weather, would be a great deal affected by the millers in the upper streams shutting the water in. Up the Reading river and all the upper rivers, and up the Colne, every miller opens his sluices on Saturday night at 12 o'clock to wash out (as he says) his weeds and mud, if he can, and on Sunday afternoon he shuts in a store until he begins working on the Monday morning, and that amount of storage, although small in each mill, becomes quite a large quantity in the aggregate, and is very much felt; but the river runs the more from this in the other days in the week.

3321. Looking to the whole valley of the Thames above Kingston, do you think it quite practicable, by the provision of storage reservoirs for the flood waters, to take a much larger quantity from the Thames basin without any injury to the river below Teddington?—Yes, and not only without injury, but with very great advantage. Owing to the operation of the millers shutting in, and the flushes, and so on, the river is unequal. Even if you could add as little as 100,000,000 gallons a day to the river by reservoirs, it would very materially improve the character of the flow.

3322. Supposing that it were proposed, in addition to the 100,000,000 gallons which the water companies have power under existing Acts, to take an additional 100,000,000, do you believe that by proper arrangements and storage reservoirs that 200,000,000 gallons might be taken without injury to the river?—Yes, and even almost with advantage. You can store spring water above Oxford, and you may make a reservoir there for about 700,000*l.* to 800,000*l.* that should secure an additional flow during the summer months of 100,000,000 gallons a day. In round numbers, I think you might manage, for an expenditure of something like 800,000*l.*, to secure that the river at Kingston should never be less than 500,000,000 gallons a day, that is of course including what the water companies might take. When the river Thames is flowing 500,000,000 gallons a day, it is a fine body of water,—a fine grey deep-coloured water, and not weedy, but when the river flows down at the minimum, and it is the very hottest weather, of course the weeds are busy in growing, and the river has a weedy character which it would be very desirable to get rid of. But a reservoir on these rivers must not be looked on as a reservoir in the sense of a mountain reservoir. It would not be made to store flood water in the ordinary sense, but flood spring water. I have seen the river Thames above Oxford, and I gauged it twice this year at a point where a reservoir might be made, the one occasion being within two days of the melting of snow and a heavy flood, and the other being within eight days, and the water was clear in both cases, but in the latter case it was the clearest water I ever saw in a river in my life. The river was in flood; the whole of the marshes of the upper Thames were under water, and yet the water was absolutely pure. There was then flowing sufficient to have filled the reservoir in about a month with the finest water I ever saw in my life, without a mixture or a cloud of any kind whatsoever. It was remarkable water, and that was at Newbridge, above Oxford, on the Oxford clay. I was not previously very well acquainted with the river in flood time up there, and I had the river analysed for the purpose of seeing the nature of the water, and I was surprised at the small amount of clay that there was in the water. (*The witness produced a map of the basin of the Thames, and explained it to the Commission.*) The river drains the oolite hills in Gloucestershire, and the district is almost as sparse of population as any in England.

3323. (*Chairman.*) What was the analysis of the water?—It was the usual analysis of hard chalk water.

3324. What was the degree of hardness?—14°.

3325. What was the quantity of organic matter?—Scarcely any. If the Commission will allow me I will hand in the following analysis:—

W. Beardmore, Esq.

16 May 1867.

CHEMICAL EXAMINATION OF THAMES WATER when in flood, taken near Oxford, by Mr. Dugald Campbell, analytical chemist, of Quality Court, Chancery Lane.

Bottle marked "Specimen of the Thames at Botley "Bridge, Oxford, near Great Western Railway Station, "taken at 11·45 A.M., March 22, 1867." (High Flood.)

This water, when viewed in bulk, has a slight yellow tinge, and had no unpleasant taste or odour.

The total solid contents per gallon were 20·40 grains; consisting of—

Mineral matter - - - - -	16·20	"
Volatilized matter by carbonization	4·20	"
Oxidizable organic matter contained in the 4·20 grains volatilized matter	1·28	"

Degrees of hardness 10·5°.

Specimen marked "12 noon, April 5, 1867. Thames "water taken at New Bridge, about six miles from "Abingdon, on the Upper Thames (470 square miles "drainage), volume about 40,000 cubic feet per minute, "10 days after the top of the great flood of March; water "still over the marshes, but now of a beautiful grey colour "and purity. N.B."

This water when viewed in bulk had a very slight yellow tinge, and had no unpleasant taste or odour.

The total solid contents per gallon were 21·80 grains; consisting of—

Mineral matter - - - - -	21·20	"
Volatilized matter by carbonization	0·60	"
Oxidizable organic matter contained in 0·60 grains of volatilized matter	0·252	"

Degrees of hardness 14·5°.

3326. (*Sir B. Phillips.*) What amount of water do you consider necessary per head per diem?—I do not think that you can give a liberal supply, taking in the chances of waste, under 25 gallons per head per diem, excluding trade and public supplies.

3327. Including those, what should you say?—I do not think you will ever hope to do it with less than 35 gallons, the waste is so enormous.

3328. Taking the present population of London at 3,500,000, and the prospective population within the next 20 years at 5,000,000, what is your opinion as to the supply of London from the present sources, from the Thames and the Lea?—I think with such a reservoir as is shown on the map above Oxford, and a moderate reservoir on the Lea, you may take 300,000,000 gallons from the joint sources, and still leave the Thames with its minimum flow below Teddington the same as at present.

3329. What is your opinion as to the quality of the water supplied from those sources for the uses of the public generally for sanitary and domestic purposes?—I think that with proper arrangement of reservoirs the quality may be faultless, always excepting the carbonate of lime, which I regret to see published every week as so many grains of impurity, being merely a solution of pure chalk in the water. It is called in the papers impurity, but setting aside that carbonate of lime you will never get a purer water. In fact the new river is as pure as Loch Katrine now very generally, and with reasonable arrangements you may have the water still purer.

3330. Then you think that 300,000,000 gallons per day could be supplied, and that if the impurities which now pass into the water in the form of sewage and other impurities could be kept from the river and from the tributaries, we should have sufficient in quantity and as good in quality as we could desire?—A perfect water, setting aside what the public are now calling the impurity of 16 grains of chalk per gallon, which, in my opinion, is a great protective to the quality of the water; it is a guard against other things, if you exclude that you are always liable to have a solution of other substances. But in taking supplies from chalk rivers you ought not to take the water during heavy floods. It would be a great improvement to the supply of London if the companies were not obliged to take the water during the worst of the flood. No river is without impurities when the first flush of heavy rain comes, for instance the rains at the latter end of October and the January rains, but especially those at the latter end of October when the water flushes down a good deal of mud and dirt which should not be taken. In that respect the supply might be improved. On the Lea practically they have for years arranged to pass the water by in flood time. The East London Water Company have made during the last five years very large reservoirs partly with that object, so that the sluices should be shut down and the river let to slip by when it is foul, and then they take their water out of the reservoir. The New River Company have done the same for a number of years. They made 30 or 40 years ago reservoirs at Newington for the same object and also at Cheshunt, so that they shut the gates down when the river is in high flood and I think that in that respect the present draught of the companies might be improved.

3331. (*Chairman.*) You have stated that the quantity from the Thames basin and from the river Lea would be ample to supply the present and prospective wants of the metropolis, and also that the quality of the water might be as good as anybody could desire; setting aside the impurity of the chalk, which you do not consider an impurity, and excluding sewage and other impurities from the water, how would you propose to exclude the sewage and other impurities from the water?—By the new arrangement legislated for last year, by which the large towns are compelled to deal with their sewage themselves within three years, and I think within two years of the present time the large towns have to divert the sewage and distribute it over land. I do not see any other way of doing it.

3332. What sized towns do you refer to?—All towns with above 3,000 inhabitants, or in fact all towns that choose to have pipe drainage. Pipe drainage is an enemy to rivers. If you leave a town on the ancient system of cesspools, and they deal with their sewage in that way, practically nothing comes into the river except just during a short period of the first flush of heavy rain, and that is why I think that no company should take water from the river during the worst of the flood, when a great deal of filth is washed out.

3333. Cesspool draining is not considered a good system of drainage for a town, is it?—That is another thing; but if they go into pipe drainage, they ought to deal with it themselves.

3334. Is not the opinion of the present day against the system of cesspool drainage?—Yes, certainly.

3335. Then we must assume that the towns will not have cesspool drainage, but will have pipe drainage if that is the best system, and in these enlightened times we may assume that that system will be followed, or ought to be?—Yes, and they ought to throw the sewage over the land. No doubt that is the best way and the only way; all the other ways at present known, unless you go to very great expense with regard to charcoal and so on, are not perfect.

3336. (*Sir B. Phillips.*) Have you considered at all what will be the probable cost of the increased supply from its present quantum to the 300,000,000 of which we have been speaking?—The mere making of reservoirs sufficient for increasing that amount from the Thames and the Lea, and adding reservoirs such as the companies might draw from, whilst the worst of the flood is passing by, would not exceed in all about 1,500,000*l.* Beyond that amount it is a mere question of so much more coals, more engines, and more pipes; but that part of the question is being met every day because the companies are adding more engines at this moment. The Chelsea Company have now just doubled their power, the Grand Junction Company has been going to double their power, and the East London Company is going to add one-third to its power this summer. They are now building the engines. All that is in process of operation at this moment. If you continue the system as at present carried out by the companies, they must go on increasing their pumping power and other means of

distributing water, for the demand is increasing every day.

3337. (*Chairman.*) Do I rightly understand you that the only impurity which you consider the water now coming to London is charged with, is the sewage of the towns in the neighbourhood of the district through which the water comes?—Yes, that is the only impurity beyond refuse from papermaking up the Thames which is now prohibited by law.

3338. If we could assume an impossibility for a moment that there were no town in the district through which the Thames comes to London, would you say that the water would be pure?—Yes, certainly, because in point of fact the rivers from those tertiary districts are composed nearly all of spring water, and the general flow during dry summer months is absolutely spring water; there are no surface runs at all.

3339. Would not agricultural operations affect the water?—Certainly not except in heavy rains, agricultural operations have never been found to affect this district except in heavy rains.

3340. Assuming that there were no towns, or what might be equivalent to it, every town providing for its own sewage, you would consider the water to be quite as pure as you would wish it?—Certainly, the water of these rivers is in fact, during dry weather, spring water, and if you wish to collect the greatest amount of spring water for supplying London you must go to the line of the rivers, there you have the maximum of spring water, the river beds are in fact springs. The feeders of the Thames from Goring to the Duchess of Sutherland's must consist of spring water, for the hills surrounding have no streams; you may go 10 miles at a stretch opposite Reading without a stream; everything is swallow country, and the water all goes down into the chalk and finally has its vent, as spring water, either in the bed of the river or close to it.

3341. (*Sir J. Thwaites.*) Are you referring to the district above Maidenhead?—Yes, from Maidenhead to Goring the Thames passes by a gap through the chalk hills, and the whole of the country is streamless, with the exception of one or two branch rivers which are also chalk rivers and a set of springs, and if you wish to devise a scheme to get the greatest amount of spring water for London, you ought to take the Thames on the line of its course and the Lee in the line of its course. The river Lee from Ware downwards for about six miles is one mass of chalk springs; the springs either flow out in the bed of the river or within 100 to 150 yards of the stream.

3342. (*Mr. Harrison.*) Your view would be, as I gather from what you have stated, to apply the same principle to the Thames that is already partially adopted in the case of the Lee and the New River; that is to say, to preserve as much as possible the spring water in reservoirs, and in times of flood pass the turbid waters off?—Yes.

3343. And adding to that the powers which under the Act passed last session were given to the Thames Conservancy Commissioners to compel all the towns to utilize their sewage instead of pouring it into the river, your belief is that the Thames valley would then supply a water which would be pure in every respect except that of hardness?—Yes.

3344. Have you given much attention to the difference between hard and soft water?—I have of course had a great deal under my notice. I was originally in my early life engineer to a waterworks company which took water from Dartmoor. It was perfectly soft water, and I certainly have a great opinion of soft water; I like soft water very much.

3345. Having a choice between hard and soft, you would not hesitate a moment as to which you would choose?—For general use certainly I should choose soft water; but with a mixed population, unless you bring water in enormous volume and waste it away greatly, I doubt whether chalk water would not keep better than soft water in cisterns, and so on; chalk is a preservative against the solution of other matters, there is no doubt about that.

3346. Have you given much attention to the question of constant service to towns?—I have had it under my notice a great deal, and in that respect I know a good deal about the subject.

3347. Taking the question of the existing system of tanks in different houses, even if a constant service were supplied, would you continue those tanks, or would you consider it necessary to abolish them, and to have the water direct from the pipes?—You must have cisterns. I do not see any possibility of dealing with the general humanity, as you may say, without them. If you have such waste as you have in the low districts in London no pipes can furnish water constantly and with high pressure. You cannot deal with it. If you have a fraudulent or a careless man in one house he is wasting water away, and of course he is diminishing the head of the person next door, that is the difficulty you have got—to protect everybody and to give an equal pressure.

3348. Then that goes at once to the question of constant supply?—Yes.

3349. At the present moment the system is for the companies to have their mains, and then they distribute the water in the particular district, shutting one or more service mains off at a time?—Yes, so as to check the waste. The East London Company, you are probably aware, do give a very large amount of constant supply now. They have given 25,000 houses a constant supply, but they do it by placing a small diaphragm with a pin-hole ferrule, as it is called, inserted in the serving pipe, so that if the cock is left open there can be but a certain amount wasted. By that means they protect the district, as it were; they are giving a constant supply on a very large scale indeed in that sense, but it is not the sense that you mean by constant. You mean a plan by which you shall open a tap, and have a spout of water whenever you like, but they give it by a very small diaphragm, varying from one-twelfth to one-thirtieth of an inch in diameter. Then they always require a cistern, so that if a party chooses to open the cistern and let the water run off he must wait for the water to dribble in again. At this moment I have the general advising and management of a small board of health town near London, and we profess to give a constant service, but it is perpetually breaking down; one wrong-doer opens a cock and there is the whole thing at an end, and we have perpetual difficulties, and now I am dividing the services. We pump under 170 feet pressure, and we are going to give the low district a separate service in consequence of the enormous waste. In that district instead of a cistern an application called a preventor was used, by which when the watercloset handle was drawn a given amount of water only could flow into the closet, but the precautions are always evaded. The parties have only got to open the cock gently and the water dribbles away, and the waste is immense. We do not know what to do to prevent it, it is a perpetual annoyance, and then the fact of a turncock going round and complaining to people is very annoying. I do not think Londoners would like to have a turncock perpetually coming in and saying you have got something wrong. In some cases under my management I had notices from them ordering me to mend the taps and things of that kind. Of course it was an expense, and I wish to have an alternative service; it appeared to be suitable to the particular district to put on a constant service, and we have had it in use for some years, but it requires very good fittings. With the pressure that is necessary you must have very strong fittings. In the district that I referred to at Enfield, I have reduced the pressure from 170 feet for the low district to about 35, and the landlords of the houses have already thanked us for doing it. They say they are delighted at it. The expense of keeping up the fittings was so great that they liked the low pressure better.

3350. (*Sir J. Thwaites.*) Are you aware of the system in operation at Glasgow and Hull, where they are under constant pressure?—I know that it is constant pressure in Glasgow, but Hull I am not acquainted with.

N. Beardmore, Esq.

16 May 1867.

3351. You are not aware that in Hull, where the system of constant pressure is in operation, instead of waste being the result a saving of 25 per cent. has been occasioned?—Yes, and there is a great saving in Cambridge, but the supervision in Cambridge and the quantity of water used is so small, that no one would stand it in London. The supervision is close, and they put overflows there which shall flow down on people's heads from over the door.

3352. What number of gallons per head per diem is the consumption in Cambridge?—I think it is as low as 20 or 22 gallons, but there are no manufactures carried on there.

3353. That would be almost sufficient, would it not, for any ordinary population?—Yes, quite; of course they can do it where they have very active managers.

3354. Do not you think that if they had such active managers in the East London district the same result would follow?—I cannot say. I think that Londoners would not like the kind of supervision which must be given with constant service.

3355. Do you mean that the London house proprietors would not like the commencement of the alteration, which would entail a certain amount of expenditure?—They would not.

3356. Supposing that your pipes and everything were adapted for a constant supply, with proper supervision, can you see any difficulty in that system being carried out in London?—It might be done with a thorough amount of supervision with the expense once started with, but I should doubt whether you would be better off.

3357. Has not the failure of the constant supply system in the metropolis resulted rather from the companies adopting the constant supply under a pressure beyond the resisting capacity of the pipes and the imperfect arrangement of taps by the householders, as well as the want of general supervision?—I could hardly form an opinion. The whole of the supply of London has been a growing thing, and you have a great deal of trade supplies distributed very much through the district in all directions. I can scarcely form an opinion about it; on the whole I never had cause to complain of the water myself when I lived in London.

3358. You have of course lived in respectable houses all your life, but taking it as a general sanitary question, are you of opinion that the health of the inhabitants would be promoted and sustained by the adoption of the system of constant supply as contrasted with the intermittent system which is now in use?—I cannot say that, because I think the real evil is the iniquitous state of the poorer class of houses. They have no sort of cistern at all, and if you made it absolutely requisite to have a very moderate amount of cistern, and proper arrangements for taking in the water, and could keep the people from stealing the apparatus, you would be as well supplied by the present system as by the constant system. At present, in the low parts of London, in the east of London, you cannot keep a tap on a pipe at all; everything goes. It is a very large district at the east end of London; and the supply is afforded practically merely by open service pipes, so that when the water is turned on there is a great deal of waste, because no one cares to keep proper taps on the pipes. If you could have a general law making the landlords of small properties responsible, binding them to keep proper conveniences, you would do it; but what are you to do? What are you to do with a district like Limehouse, where you cannot keep a tap?

3359. (*Sir. B. Phillips.*) You say that you cannot keep a tap there, how do you propose that the landlord should keep those things?—If the landlord was bound to keep the cistern in proper order, and if he saw to it every Monday morning, and told the tenants that if the tap went he would turn them out of their rooms to-morrow and would summon them, it might be managed, but it is a very difficult question, indeed, to know how to do it. It is a question entirely for the landlords, and not for the companies. The water companies have plenty of water, whether it be the constant or whether it be the intermittent system; there is plenty of water, but there are no conveniences for taking it. Just apply the case, for one moment, to the question of gas. Supposing it were said, you give us plenty of gas outside but we cannot see in this room, and you went into a house and found that they had provided no gas pipes, or rather had cut them all off, you would not find fault with the gas company. That is the case with the poorer districts in London, with regard to water. It is utterly impossible to keep anything in the shape of proper fittings for a habitable house.

3360. (*Chairman.*) I am afraid that would go against any supply of any sort?—Yes; that is the reason why I say that the difficulty is not one of constant supply, but a difficulty as regards the detail of distribution.

3361. (*Sir B. Phillips.*) Supposing that the difficulty could be overcome, would you then recommend a constant supply in preference to an intermittent one?—I would scarcely go so far as to recommend it, but I think a constant supply would be much easier of attainment. In order to have a constant supply you must have an even pressure, and if you have two or three wrongdoers in a small court who are drawing all the water out, where is the pressure? You cannot do it.

3362. (*Sir J. Thwaites.*) I suppose there would be no difficulty in having some mechanical arrangement for the purpose of watching the condition of the pressure in the pipe, whether it is being exhausted by wrong-doers, as you describe them, or discovering whether the things were in a satisfactory condition?—Not the slightest difficulty; you might put pressure gauges.

3363. I mean that some pressure gauge might be fixed in a court of 20 houses to determine the pressure, and if the pressure indicated something wrong the officer could just go in and see for himself?—Yes; you may have a pressure gauge fixed to a lamp post in every principal street, if you choose.

3364. If it were made a condition of the tenancy that those arrangements should not be interfered, it would very soon operate upon the tenants themselves, would it not, because if they found that unless they left those taps and things to work in their proper course they would have to leave their lodgings, that would soon tell upon that class of persons?—Yes. You are aware that the local authorities have now power to compel a landlord to do those things, but they never exercise that power.

3365. The great mischief is the faulty receptacles which the poor have for the purpose of storing their water, is it not?—Yes.

3366. And that invariably, in consequence of the absence of any sanitary knowledge, they will place the water just where it can be contaminated, that is to say, just where it can take up the gases which are generated either in privies or ash-heaps, or where any filth is deposited and decomposition is going on, and, of course, the result is fever in every form?—Yes, I think myself that the poorer districts of London would be very much improved in their water supply if there were public standcocks for the courts, where the people could run out and get their jugs full at all times, and be constantly supplied. There would be no doubt that the companies could do that with the greatest facility. The Carlisle and Nottingham supplies for courts and small rows of cottages are all done in that way; they give one or two standcocks to a row of houses; and they give no interior supply at all in these and many other towns, to certain classes of property.

3367. (*Sir B. Phillips.*) Would it not be a much safer principle to supply those small houses with standcocks?—Yes, if you had the power of levying a rate upon them. I take it that it is rather a financial question whether the landlord would not say that he would not pay the rates unless you put the water in the house. But in Carlisle, Lancaster, Notting-

ham, and many other towns, I believe that they pay the rate just the same. I happen myself to be the owner of some small property in Nottingham, and I pay the rate for every house although I have only a standcock in the centre of my court.

3368. Supposing standcocks were placed in the courts with a constant supply for the inhabitants of small tenements, as you say, the probabilities are that the landlord would say, "I will not pay the rate unless the supply is brought into the house;" but if the water were brought into the house and he had to pay the rates do not you think that that would be a great security for the supply in the house being better looked after?—Yes; but he has to pay the rates now.

3369. I understood you to say that if there were a constant supply in the court it would be a financial question, and the probabilities were that the landlord would not pay the rates for the houses because the water was not supplied in the houses?—Yes.

3370. Supposing a case like that were to arise and the landlord were to say, "I will not pay the rate because "the water is not brought into the house to supply the "inmates; bring the water into the house and then "I will pay the rate;" do not you think that in that case it would be a great guarantee that the landlord paying the water rate for the supply of the house would see that all the appliances were kept in good order?—The only guarantee would be in compelling the landlord to do it. Practically the landlord takes no notice of it. The waste goes on and he takes no heed of it; he looks for his rent and he pays the outgoings. If you made it compulsory in this way, that the company should be bound to find within a reasonable distance a standcock, and to maintain it at their own charge and charge the buildings with the rates, I think that there would be less waste, and practically a better supply for the people who would run for their water to this cock.

3371. Are you aware that during the recent cholera outbreak in the east of London some of the water companies supplied standcocks gratuitously to the poorer districts?—I believe they did so.

3372. Do you know what was the the effect of that?—I do not.

3373. Then really, in other words, if I understand you correctly, you object in one way to the constant supply, but you approve of it in another way; that is to say, you approve of the constant supply by standcocks in courts?—Yes. I say it in this way, that with a standcock in a court, for some half a dozen houses, under the open control of the company, there would be proper security against waste, but if you give the water to all the houses in the court there would be an immense deal of waste, and all the fittings would have to be multiplied. I think that if the landlord were relieved of the expense of all those fittings, and had a standcock instead, he would be very thankful, and the people would then have the water to go to. But there would still be the question of waterclosets left.

3374. But I still understand you to recommend standcocks for the supply of those small courts?—Certainly. I think that it would be a very great improvement if standcocks were placed in those low neighbourhoods.

3375. (*Chairman.*) You stated that if standcocks were placed in courts under the control of the company it would be an improvement. In what way do you mean that they would control them?—I think that the company would not be very much burdened, the standcocks having been once erected by the authorities, if they maintained them and just kept them tight; and they would have a very strong interest in doing that, and the company would hardly feel the expense of it. Speaking practically, the standcocks, which are merely those wooden things that are put into the plug, and that they use in times of frost, are always maintained by the company; but if the system were adopted permanently, there must be something better than those.

3376. There would, in that case, as Sir Benjamin Phillips observes, be a constant supply?—Yes.

3377. So that any person in the court could go and take the water from this standcock whenever he pleased?—Yes, he would lift the ball and turn the tap.

3378. Might he not leave it half open?—I think that it could be arranged by the ball in some way or other so that there need not be any waste in that way. And I think that, it being a public thing, the company would naturally look after it, because the expense would be very little.

3379. Supposing that those standcocks were put up in the courts, there would be no reason, would there, why there should not be also water supplied for the waterclosets?—No, not at all.

3380. Because, although there might be some waste in the supply to the watercloset, there would be less waste by taking the water from the standcock out in the house?—Precisely so. Of course you could not keep the waterclosets sweet without having a supply of water to them.

3381. You have stated that the quantity of water in the Thames basin is ample, and you have described the quality as good, save and except that impurity which you do not admit to be an impurity, have you gone into the medical question of the water, as to whether hard or soft water is better or worse for health?—Not otherwise than applying my own knowledge to things in general, and knowing that the majority of mankind drink hard water, and look for hard water. It is very remarkable how they avoid soft water for drinking.

3382. Are you speaking now of water of from 12 to 14 degrees of hardness?—Yes. It is very remarkable how mankind always look for hard water to drink. I recollect some years ago being engaged in some mountains in Spain, where we had soft water running by, and the inhabitants would never give you that water; they would refuse to give it you, and that struck me very much. They would say that it would give you the colic. That is the general impression, and it is so everywhere. All mankind go to hard waters for drinking, as a general rule. In my own house in the country we use very hard water, harder than any water that there is on the Lea valley. We use the hard upper water of the valley coming out of the gravel, and we enjoy very good health. Of course there is a water that transcends all water, and that is spring water from the granite. That is pure water, and absolutely soft, and it is the water that you go to drink at Malvern; the water dribbling out of the rock there is absolutely pure water. There is also a spring of it in Dartmoor, which I have often drunk with very great pleasure. It is absolutely pure water, and if you get it when fresh out of the ground is really charming water.

3383. Have you ever been in Scotland?—Yes, I have been in Scotland a great deal.

3384. What is the character of the waters in that country?—Some of them are wonderfully pure. Some of the waters flowing out of the slate rocks and the granite rocks are of that character, beautifully pure.

3385. Have you ever been up as high as Aberdeenshire?—I do not know Aberdeenshire very well, but I have been there.

3386. Would the water there be likely to be of that character?—It is chiefly soft water. There is some hard water in Aberdeenshire, but the soft water is exquisite water as a general rule. There is such an immense quantity of granitic drift in Scotland. Take the wide world, and go to Russia or to Germany, or through the whole length of France, and with very few exceptions you will drink the hardest water.

3387. What I gather from your evidence is, that although you would prefer soft water to hard water, if you could get it for ordinary cooking and domestic purposes, and possibly for washing and possibly manufactures, yet as regards health, judging from the circumstance that the bulk of mankind drink hard water, you would not care to get soft water for the

N. Beardmore, Esq.

16 May 1867.

metropolis on that account?—On that account I should not.

3388. (*Sir B. Phillips.*) Do you think, in one word, that the water supplied to the London public from its present source is prejudicial to the health of the metropolis. I am, of course, speaking of pure water divested of all its impurities?—Certainly not, I was a good deal in the infected district last year, in the east of London, and I think that the whole of the out cry was perfectly baseless, as regards the cholera having anything to do with the water supply.

3389. (*Chairman.*) Will you identify the particular district which you are now speaking of?—I mean the district where the cholera raged so intensely in the east of London.

3390. Do you consider that the prevalence of cholera in the east of London last year was not attributable to the supply of water in that district?—Certainly not.

3391. Will you kindly give us your reasons for coming to that conclusion?—First of all I drank some of the water myself at every opportunity, to try it, and I had a large number of labourers and navvies under me at the time in the worst district, and where the foulness of the Limehouse Cut was the greatest, and scarcely a man was free from an attack of diarrhœa, but I should doubt whether any one man drank the water at all except in the form of tea, and there was quite filth enough in the neighbourhood in the water of the Lea and in the defective drainage, and in the close habitations where the men lodged, to account for the attack of cholera. An accusation was made against the East London Company that they let in the water from a certain reservoir and mixed it with their district supply. I had under my own cognizance several families who drank nothing else but the water which furnished this very foul supply as alleged; they had young children and some of them delicate children, and yet they were more free from the attack of the disease than the general run of the neighbourhood. I attribute that to the fact that they were living out of the thick neighbourhood in open ventilated places, but those families were absolutely drinking and living upon that water, the children and all, and there never was a death amongst them. If the Commission wish to learn more of this subject perhaps I might suggest to them the name of the medical officer of health for the Limehouse district with whom I was in constant communication, because I was carrying on works that compelled me to keep the Limehouse Cut deodorized, and I saw him constantly. I found by accident a little time since that he published a report distinctly giving it as his opinion that the water had nothing to do with the outbreak of the cholera. The gentleman I refer to is Mr. Orton, the medical officer of Limehouse, a very intelligent man, and one that had the best opportunities of knowing. I very much fear that the cholera was caused by the use of bad pump water; there is no doubt about a large amount of pump water having been used. I think that in Jubilee Street, Mile End, it turned out that the houses that were attacked the worst were all using pump water fetched from a greengrocer in the street.

3392. (*Mr. Harrison.*) Has it not been found that a leakage was actually taking place into the reservoirs through the bottom from the river Lea?—No, it was suggested by a medical gentleman who went down that there might be a leakage.

3393. Is it not the fact that Captain Tyler has had those reservoirs emptied and discovered that that actually was taking place?—I did not know of it.

3394. I think you will find that it has been admitted to be the fact that into those reservoirs an actual leakage from the river was coming in at the bottom?—If Captain Tyler examined it of course he pumped it out, and then there may have been a leakage, but how could there have been a leakage when there was no pressure?

3395. If there is a connexion between the two, of course the effect may have been so?—But how can there be leakage with no pressure?

3396. The water of the Lea may at times have been higher than the water in the reservoir?—Yes. However, the abomination of the smells and the foul ditches were so great in the neighbourhood that it was enough to make anybody ill to go for a moment into any part of the district, particularly where the cholera actually broke out at Bow. No words that I could use could describe the abominable stench that came from a paper works there. The first of the number that was seized in that street at Bow worked in a low shed in Stratford, by the side of a ditch which came from a yard where they took all the foul matter from the London markets, and boiled it down for fat, and the foulness of the place and the closeness of it altogether was something beyond description. That was at Stratford. They were taking 30 tons of meat away from Leadenhall market at that time and boiling it down in a putrid state, and it infected the whole district, and the refuse went into a ditch which flowed by where those people who were first attacked worked.

3397. (*Mr. Prestwich.*) You have given us the gaugings of the Thames and the Lea, have you any gaugings of the Severn?—No. I calculated the flow of the Severn many years ago in the lower part, but I have no data with regard to the Upper Severn.

3398. You do not know what the flow of the Severn would be at Shrewsbury?—No, I do not.

3399. You gave us the mean daily fall for the period of four months of the driest years for the Thames and for the Lea; do the papers which you have put in give the mean fall for the entire year of the driest year?—Yes.

3400. (*Col. Harness.*) Do you consider that the large reservoir which you propose near Oxford would be sufficient alone to ensure a minimum supply of 500,000,000 gallons a day at Teddington?—Practically that reservoir alone would give very nearly that quantity.

3401. What capacity do you propose for that reservoir?—That reservoir would contain, I reckon, 100 days supply, at 100,000,000 gallons a day.

3402. Can you give us some idea of its surface and depth?—Such a reservoir would be nearly 2,500 acres in area.

3403. That is something under four miles, is it not?—Yes.

3404. And what depth would it have?—It would have not less than 16 feet of depth. I think it can be arranged to have more depth than that. Of course the surveys that I have made are only preliminary, and they could be improved upon a good deal.

3405. Does the site offer much facility for making it there?—Yes, it is a very good site indeed; it is steep on one side, and the other side would have to be embanked. It would be at Northmore, near Stanton-Harcourt, that fine old place that belonged to Lord Chancellor Harcourt. Why such a site as that would be selected is this: It is a great object to have depth to the reservoir, and the valley is so flat that it is quite difficult to get the depth, and I propose to make a tunnel down to Abingdon, so that you could put a dredger in at any time, and deepen the reservoir.

3406. In making the reservoir, on one side you would have a slope, would you not?—Yes.

3407. Would the whole of the remainder be embankment?—Yes.

3408. Then you would get a great length of embankment?—Yes, I should excavate about 12,000,000 cubic yards for the sake of getting depth.

3409. Is there a great depth of the Oxford clay there?—I do not know.

3410. Have you in your experience been able to find out whether there is any important amount of leakage in any of the large reservoirs that are made in that way?—The advantage of a reservoir in this site would be that there would be no leakage, on account of its being clay and its being excavated, and there would be no pressure to leak from, and I should

hope that a reservoir could be made there with a depth of 20 feet, and I think that it would be a success.

3411. Have you made any observations upon the leakages that take place in the large reservoirs that are in existence?—There have been some large reservoirs made where a very great amount of leakage has occurred under a heavy pressure, but no reservoir would be made in any of those valleys with that amount of pressure, such as 70 or 80 feet; that is a different kind of thing, of course. We know that there was some leakage at Rivington Pike, for instance, owing to water escaping through some old quarry workings, and thus creating an artificial spring; and they have had very great waste in some of the Bradford reservoirs, but no reservoirs in this district would be anything like approaching to that class; they would be more of an artificial character altogether, and with comparatively small pressure. When embankments exceed 50 feet in height the leakage is much more difficult to deal with than at lower pressures no matter what the soil may be.

3412. Are you aware of any facts which have been published with respect to the leakage of large reservoirs?—The French have published a good deal on that subject and on the loss of water, and they calculate it to a nicety in the head district of their Great Eastern Canal, but I do not think that anything has been published in English upon the subject.

3413. (*Mr. Harrison.*) Instead of excavating such a reservoir to a depth of 12 feet it would merely require you to bring your conduit into it, a mile or two further back, and you might then regulate it to such a depth as would balance the amount of your excavation and embankment?—Yes, that could be adjusted; I should hope to get a reservoir there for within 800,000*l.* and I should have 20 feet more water by proper dredging if you like below that. Of course a puddle gutter would be carried all round the reservoir so that you could dredge or do anything you like with the interior afterwards.

3414. (*Col. Harness.*) The water from that reservoir at Oxford would still pass by the bed of the Thames, would it not?—No, it would be passed throug a tunnel to Abingdon on account of the difficulty of drawing off. The bed of the river above Oxford is so excessively flat that you can scarcely do anything with it without making a tunnel through to Abingdon, and there you have the advantage of carrying the water sweeter and cooler down the main body of the river, and you avoid any impurity in passing Oxford. The stream is so flat there that you can never get a rapid stream, it would always be sluggish in the valley.

3415. You spoke of a large amount of springs which entered the streams both of the Lea and of the Thames between Goring and Maidenhead valley. Have you ever measured the accession received by those streams from the springs alone where no tributaries flow in?—I have attempted to do it by gauging the river above where it entered the chalk district, and also below. I have attempted to do that some years ago when the river was in a low volume, and I ascertained sufficient to prove what we almost knew; viz., that there was a great increase of water, but I have never calculated it out. It was a very large accession indeed, and I will just show it on the map (*producing a map and explaining it to the Commissioners.*)

3416. (*Sir J. Thwaites.*) Does that represent the whole of the Thames?—It does not represent the whole of the basin, but that nearest to the Thames. Mr. Prestwich perhaps will tell you better than I can, that beginning a few miles above Reading, and passing over the north of the Thames to the Colne, it is almost a streamless district of bare chalk, or covered by the Bagshot sands which absorb all the water. It is intersected by a very fertile chalk stream which flows up by High Wycombe, and also by a branch of the Colne, and I take it that from this area there is something like 300 square miles of absolutely pure water drainage. I do not think there is any water at all that is not spring water which flows out of it, except under very extraordinary circumstances.

3417. I understand that the place indicated by this colouring on the map would be an excellent site for a reservoir, and the area would be about four square miles. Can you give us any description of the surface occupation, whether it is valuable agricultural land, and whether there are houses or railways or anything that would interfere with the formation of a reservoir there, or if not, whether the purchase of that four square miles would be very expensive?—It is mostly drowned marsh land which gives a very good crop some years, but in some summers no crop at all, and there are scarcely any houses upon it.

3418. There is a village here (*pointing to the map*)?—Yes. Of course you would shut out the village. There are scarcely any houses, and the pressure of a reservoir like that would be *nil.* The ground would be excavated at least nine feet, the bank of that reservoir would not be above ground altogether more than 12 feet.

3419. Are those pasture lands?—They are very wet marsh lands, averaging 25*s.* to 30*s.* an acre; it is not rich land like the Thames valley below Oxford.

3420. (*Chairman.*) Does it carry any stock upon it?—They take hay off it and it carries stock.

3421. They would get more than 25*s.* an acre for that land, would they not?—I doubt if that land is worth more, because some years they lose their crop. In a wet summer they do not have any crop at all, there is a certain degree of risk withit; they get from 25*s.* to 35*s.* I should think for some of it; some of it is better than others, some of it lies a little higher.

3422. (*Mr. Prestwich.*) You stated that you had made some gaugings in the lower part of the Severn valley, how low down did you go?—I calculated it from a survey made by the Admiralty some years ago, but it was quite the lower part of it, after it had received its tributaries, and it would not be at all applicable to the subject of the present inquiry. Shrewsbury would be too low to gauge to give any idea of what you would really get, because you would not get enough rain; there is much more water in proportion to the area as you approach the mountains.

3423. But would not gaugings a little above Shrewsbury give the daily flow of water from the district described by Mr. Bateman?—I would rather go higher, because you would be gauging the water from a country having a lower rainfall. To give the fair amount of rainfall the gaugings should be further up, nearer the mountains.

3424. In the table which you have put in I see that you do give the mean daily flow for the driest year, and in the driest year, taking the Thames and the Lea together, you get a mean flow of 733,000,000 gallons, which would fairly represent the delivery of the Thames basin above London, including the valley of the Lea?—Yes.

3425. For the driest year; that is the year 1864?—Yes, and excluding the Wandle and some of the Colne (one branch of the Colne, if you recollect, comes away down to Brentford), and the Hogs Mill river also. This estimate also excludes the water-bearing districts of the North Kent Water Company, and the springs there are available to the population below Dartford and over the area drained by the Medway.

3426. You stated that you had arrived at a probable law with regard to the delivery springs in the chalk, that it took a period of about a year and a half for the surplus quantity stored in the chalk to be delivered?—Yes, finally drained out.

3427. How have you been able to separate the delivery of the following year in September from the rainfall of the previous winter?—You cannot, except by inference. We know that if a dry summer follows a dry summer the land springs cease, and there is comparatively no surface flow, and we know from general facts and the general appearance of the water that it is all chalk water, in fact all water from the low springs. There is no other water in such circumstances as this; it is a pure deep chalk water

N. Beardmore, Esq.

16 May 1867.

flowing in such years. At the end of September 1864 or 1865 there was no other water at all. The river Stort, which drains a clay country, came almost to nothing in that month in both those years. That river has comparatively little chalk water in it, and it came almost to nothing.

3428. Have you observed that, notwithstanding a heavy fall in the previous winter, when there has been a very dry year before that, the springs in the September following the rainy winter have nevertheless suffered from the dry season of the previous year?—Yes, the water has not got down to them.

3429. In many towns soft water has been of comparatively recent introduction, but are there any towns in which you have been able to observe the effects of the introduction of soft water after they had been accustomed to the use of hard water?—The strongest case at all that I can recollect is that of Glasgow. Glasgow was supplied with very hard water at one time, and when the river water was used, although softer, it was liable to be foul; the south side of the river about the year 1850 was supplied by a new company, called the Gorbals Company, bringing a very soft water. That company almost supplanted the old hard water company, and then followed Mr. Bateman's Loch Katrine scheme of supplying soft water, about five years ago, to the north side of the town. The final change was made then.

3430. Have you had any opportunity of noticing the effect produced by the change upon the health of the people?—No; I know of nothing about that point. I am only pointing out that fact in order that the Commission might have their own means of ascertaining the result, if they could. There is the fact that there was a change then from hard and inferior water to very soft water. I think, if I recollect rightly, the Glasgow water was at one time very hard. I think there were sulphates in it, as pumped from the lower basis of the coal measures under the Clyde.

3431. You stated that some years ago you had occasion to introduce the Dartmoor water to Plymouth?—I was engineer to the company, and we had soft water. I quite appreciate the value of soft water if you can keep it free of peat.

3432. You did not first introduce this soft water into Plymouth, did you?—No, there was soft water there before. The great evil, of course we know, in the case of soft water is peat, but that of course you are liable to even now; even the water of Glasgow, pure as it is, will sometimes have a brown colour. I had water brought up to me in the hotel at Glasgow last year which was excessively brown, as brown as the oak in the table before me.

3433. (*Sir J. Thwaites.*) That was from the peat?—Yes. In laying out a scheme for bringing water from the Severn you must reject the bog water streams, or else they will colour a vast quantity of good water; but that is a mere matter of detail. Londoners would not stand that colour.

3434. (*Chairman.*) But that brown colour would only be after floods?—There are in those mountain streams bog water streams that are always foul. You must shut them out of any scheme. You must turn them away. You ought never to let in any bog water stream.

3435. (*Mr. Harrison.*) You could almost always do that, could you not, in any case where it was necessary?—Yes.

3436. Did you ever see the London water a little coloured?—Yes. Of course, in both cases, you should shut out flood water and anything that is likely to foul water.

3437. (*Mr. Prestwich.*) Have you ever noticed the effect of soft water upon pipes, either of lead or of iron?—No, I have never had any practical experience myself of the matter; but you are aware that iron is much more difficult to keep from rusting in pipes holding soft water than in pipes holding hard water. There is no doubt about that. The way in which our pipes at Devonport used to foul with the peat and softness of the water was very extraordinary; sometimes when the water lay dead in them and there was not much change, at the end, perhaps, of 10 or 12 years we should have to take out a pipe almost filled with a mass of unctuous stuff, half peat and half iron, and the pipes were really very seriously eaten out by it. We know that chalk water is very advantageous for pipes in that respect; the chalk deposits in the pipes instead of eating them.

3438. Where would you propose to place the reservoirs on the Lea in order to regulate the flow of that river?—I think they should be, as a matter of convenience and economy, somewhere in the neighbourhood of Waltham Abbey, but to get a proper depth, you might make a reservoir on the Lea very well with 30 feet depth, by having a feeder from the river above so as to give the proper depth of water as described by Mr. Harrison in the case of the Thames. The Lea valley is bottomed by the London clay; it is about 18 or 20 feet through the gravel down to the clay, and in any reservoir in the Lea valley you would have to puddle down that depth. I would not attempt to put a reservoir above where the London clay is. The London clay is thrown up apparently by a fault running somewhere in the neighbourhood of Broxbourne. There the bottom of the valley is London clay, and you may make a reservoir to hold absolutely tight without any leakage at all with the pressure that you would give to the reservoir there, in fact the East London Company have done so. Mr. Greaves, the engineer of the East London Company, has of late made such reservoirs, by puddling through the drift gravel down to the London clay, and in one case he went down 28 feet to the London clay, just above Walthamstow; thus making his reservoir absolutely tight. In the upper part of the valley there is more difficulty in making reservoirs. I was concerned with the late Mr. Rendel some years since in devising reservoirs on the upper branches of the Lea; we did not know much about the quantity of water that would run off at that time, and from what I saw of the borings of the beds of the streams, and the flow of water from the ground, I should not be disposed to recommend very deep reservoirs to be formed by dams across the valleys. I do not think they would be thoroughly tight, unless you could find some special areas where there is clay, which is very difficult to get. The volume of spring water during the winter months is so enormous that with a reservoir situated low in the valley, you may get practically a store of spring water for use during the dry months of summer.

3439. Sufficient to ensure a delivery of how much?—I think you might ensure 70,000,000 gallons. The table will show of itself, that many years you can get a great deal more than 70,000,000 gallons out of the Lea without any reservoir at all, but even then the reservoir becomes of use, because in a full year the river is flooded very often, and at such times, for that season, the reservoir is of very great use. I have just taken out a little statement showing about the number of days in each year that the river Lea is turbid. That is a point which the French investigated a good deal when they were studying the question of what new supply of water they should give to Paris, and practically this table, which if the Commission will allow me I will put in, will tell you the number of days over 17 years in which the river Lea was turbid. The turbid periods in 1858 were only five, in 1860 there were 26 periods of turbid water, showing an enormous difference in different years. In those dry years, 1858 and 1859, it was pure grey water practically nearly throughout the two years, but of course the volume was greatly reduced. When I speak of grey water, I think perhaps gentlemen may have seen that peculiarity. You may always know whether water is merely loaded with carbonate of lime, and is perfectly pure as spring water, by its colour. You see that in the streams of the Jura mountains very strongly; wherever the water flows from limestone it is French grey, a greyish blue colour, it is unmistakeable, and in all chalk springs you see it.

With the permission of the Commission, I will hand in this table.

The witness delivered the following table:

River Lea at Feilde's Weir.

Drainage area, 420 square miles.

Statement showing the Number of Days and of Periods in each Year when the Water was turbid, from 1850 to 1866.

Years.	No. of Days.	No. of Periods.	Mean Duration of Turbidity.
1850	13	7	1·85
1851	32	10	3·20
1852	96	16	6·00
1853	125	18	6·94
1854	24	6	4·00
1855	22	6	3·66
1856	27	7	3·85
1857	28	12	2·53
1858	12	5	2·40
1859	22	6	3·66
1860	73	26	2·80
1861	37	11	3·36
1862	16	7	2·28
1863	12	5	2·40
1864	8	2	4·00
1865	22	9	2·44
1866	53	18	2·94

3440. (*Sir J. Thwaites.*) Have you any further observations to make which you think would be useful to the Commission?—I made some remarks in the paper which I sent in as to the expense of getting water into London by gravitation, and they are to this effect:—The engineering difficulties and expense will be very great for an entirely new distribution of water by gravitation from one centre, such as Stanmore, situate 10 miles from the outskirts of the nearest point of the metropolis, and upwards of 18 miles from the furthest present point to which the London water companies supply. The expense of re-arranging the distribution of water over the metropolis so as to obtain gravitation pressure equal to that at present given appears likely to exceed any estimate that has yet been given. Even supposing that the water companies are merged into one body, there can be no doubt that the present companies occupy areas (urban and suburban) which at any rate must be considered as six districts requiring independent mains from Stanmore; thus the New River district would require a pair of 36-inch mains, from 12 to 14 miles in length each; the East London district would require a line of 42-inch mains 14 miles in length, and another line of 18 miles of the same size; the immense area served by the Lambeth and Vauxhall Companies would require four lines of 42-inch mains, and a bridge over the Thames specially constructed for carrying the pipes into the southern districts. I estimate these arrangements for all the districts at about 2,000,000*l.* A distributary reservoir at Stanmore should hold at least 30 days supply, otherwise an accident on the line of conduit between Wales and London would leave the metropolis without water. Therefore the service reservoir should hold 4,000,000,000 of gallons, or 650,000,000 of cubic feet. This should be uniformly deep, to avoid growth of weeds and heating of the water. Such a work would not cost less than 800,000*l.* and probably nearer 1,200,000*l.*, considering that its position would demand that most of it must be excavated artificially. On these data the total cost of distribution in London would amount to about two and a half millions sterling. This estimate is exclusive of the Kent Waterworks district, the revenues of which Mr. Bateman appears to include in his resources, but the distance of which from Stanmore is so great, that even one 4-feet pipe from Stanmore to Blackheath would be about 20 miles in length, and would cost about 230,000*l.* It is doubtful whether this rapidly increasing district could be supplied from a point 20 miles distant, without a second 4-feet main, unless the water were distributed through the Kent district with the assistance of the present establishment of the pumping engines. I need not enlarge upon this except to state that I think that the locality of London renders it extremely difficult to get a proper and ample supply of water by gravitation distributed over the whole area. It is the very reverse in that respect of Glasgow, where you have hills of great height approaching close to the city. If, for instance, you wish to supply water from Stanmore to the Kent district you must carry it 20 miles in a pipe alone. That difficulty arises from the locality of London itself, and seeing that the New River Company bring water by gravitation to about a height of 90 feet above high water, and that practically they pump the whole district, it is the best example that I can give you of the difficulty of supplying London by gravitation from one point. The distance is so great from the divergence of the districts that there must be an enormous amount spent in iron pipes to bring home the head to every part if you wish to give gravitating pressure. The present system of distributing pressure through London is from a multiple of centres by engine power, and to imitate that by gravitation from one centre would throw you practically into an enormous expense. If you wish to bring soft water to London by any such scheme I think it would be far more economical to graft it on the present system of pumping as much as you can. I do not say what the exact pressure would be, but that engine power would have to be used. For instance, you would supply the New River district with soft water from Stanmore far more economically by sending it to the New River head, and letting it be dealt with by the engines as at present than you would by attempting to put such an amount of large pipes as should bring the pressure over the district by gravitation alone. That is the conclusion to which I have come.

3441. (*Mr. Harrison.*) It is simply a question of the economy of one system over the other?—Yes, owing to the immense size and number of pipes which would be necessary to bring the pressure home from distant a point as Stanmore.

3441*a.* Still it is purely a question of cost?—Not quite purely so, because of course the Kent district would be almost impracticable without pumping. There would be no way of supplying the Kent districts except by using the present pumps; you have not pressure sufficient, as so much of the district is actually above anything that you could reach.

3442. (*Col. Harness.*) Having an elevation of 90 feet at the New River head you probably do supply a considerable portion of your district by gravitation, do you not?—No, very little; practically it is all done by the engine. It is pumped direct. There is a service reservoir on the top of Claremont Square into which they pump.

3443. Even for the low districts?—Yes. It happened in this way. In the year 1853, when filtration was put upon the company, they were obliged to lose from 13 to 15 feet out of the 90 feet then available, and the increased pressure required for the district and the larger volume of water that they had to give, I think I am right in saying, practically drove them to pump nearly all their district.

3444. Before that you did deliver a large portion by gravitation did you not?—Yes, a large portion of water was delivered by gravitation before that alteration with the limited supply that they then gave.

3445. (*Mr. Prestwich.*) Supposing London were supplied by high pressure from Stanmore that would probably necessitate a fresh system of pipes for London altogether, would it not?—Yes, a fresh system of large pipes to bring the water home into the present pipes. If you once got the water home into the centres of the various districts with pipes large enough for the purpose you would get the pressure, but as I understand the height at Stanmore, it is not sufficient to bring what you call high pressure into London, which is a height of 200 feet. I will just give an example which will explain what I mean. The Thames is now

N. Beardmore, Esq.

16 May 1867.

taken we will say by the Grand Junction Company at Hampton, and they pump it six or seven miles to their works at Kew Bridge, and to deliver it at Kew with a pressure of 90 feet; at this place they filter and begin their supplies; they have to pump with a pressure of from 190 to 210 feet, although they are within five miles of their district; again at Campden Hill the company re-pump for the upper levels of their district. The Chelsea Company only pump to their reservoirs on Putney Heath, a distance of six miles from Thames Ditton; their reservoirs are only 160 feet above their district in London five miles distant, and yet they have to pump up to 230 feet pressure at Kingston to get it up the six miles. That shows you the pressure which is required from any point at a great distance, and the size of the pipes for reducing of pressure necessary for bringing the pressure home. In fact, it is not a constant pressure or a constant supply system unless very large pipes are brought over that 10 miles to bring the supply even to the confines of London.

The witness withdrew.

H. H. Fulton, Esq.

HAMILTON HENRY FULTON, Esq., examined.

3446. (*Sir J. Thwaites.*) You are a member of the Institute of Civil Engineers?—Yes.

3447. Has your attention been directed to the question of supplying London with water?—It has.

3448. I believe you have some prepared scheme for accomplishing that object?—Yes, The plan which I propose is to take the water from the upper sources of the river Wye in Mid Wales, at a point about a mile and a half below Rhayader at the confluence of the Wye and its tributary the Elan.

3449. Have you any plan to show the gathering ground and the course of your tunnel?—Yes. This is a plan (*producing the same. See Appendices A A* (1) *and A A* (2), showing the different watersheds from which I propose to take the supply. No. 1 watershed contains an area of 93,752 acres.

3450. Can you go on to describe the other part of your district, area No. 2?—I had better state perhaps that the reason why I selected this district, is that it is very thinly inhabited, the water at present is scarcely used at all either for manufacturing, domestic, or navigation purposes, the fisheries which exist can be protected from injury; there are no manufacturing towns in the watershed, and the only application of water for mechanical purposes is for flour mills, of which there are very few.

3451. Are there any mines?—There are a few mines, but very few indeed.

3452. Are there lead mines?—Yes, but I believe within the last few months those lead mines have been given up on account of their being unproductive.

3453. Are we to understand that the several areas numbered 1, 2, 3 and 4 are all essential for the present scheme, or are they alternative areas?—No. 1 watershed, which comprises 93,000 acres, is sufficient to yield a supply of 130,000,000 gallons a day, that is after allowing the usual amount for compensation to mills, &c.

3454. Will you state to the Commission what is the rainfall on No. 1?—The rainfall which I have assumed is 60 inches per annum, the net rainfall after deducting for evaporation and absorption is 30 inches.

3455. What do you allow for absorption?—In that case the evaporation and absorption would be 30 inches.

3456. Can you separate the absorption from the evaporation?—The absorption I take at 12 inches, I have taken the two together at 30 inches.

3457. Therefore you would have a net result of 30 inches of rainfall?—Yes.

3458. And that calculated on an area of 93,752 acres would give you 130,000,000 gallons per diem would it?—Yes, after deducting for compensation that is the net quantity.

3459. I mean that then you would have at your disposal 130,000,000 gallons of water per diem?—Yes.

3460. And you would provide for compensation a portion of that, and the rest would be due to your reservoir?—Yes; the total quantity which I assume I should get would be 175,000,000 gallons from this area alone. Then I deduct from that amount 44,000,000 gallons for compensation, which leaves a net quantity of 130,000,000 gallons.

3461. Then your previous answer was not correct that the quantity of rain would be equal to 60 inches, and that, calculating that over an area of 93,752 acres, would yield 130,000,000 gallons?—The 130,000,000 would be after deducting for compensation.

3462. Do you mean compensation to the rivers?—Yes.

3463. You would equalise the flow, I suppose?—The flow would be equalised during the dry time.

3464. I presume that under that system of compensation the rivers would probably never be so low as they are now in the dry season?—Never; the flow would be more equable.

3465. But you would not have floods as now?—Not to the same extent, unless the reservoirs were full. Of course, if the reservoirs were full, the water would flow off as usual.

3466. If the rainfall mastered your storing capacity, then it would flow off into the river as it does now?—Quite so.

3467. How have you arrived at the conclusion that 60 inches of rain falls in that district?—There are no observations by rain gauges that I am aware of, except a few. I merely reason from the similarity of the district to the Lake District. I consider that as the Lake District is found to yield about 77 inches it is a safe assumption to take 60 inches for this particular district.

3468. Then you have no means except the analogy to which you have referred to determine the question?—No.

3469. (*Mr. Prestwich.*) Where is the nearest rain gauge to your proposed district?—There is one near Rhayader, which on the average has yielded, I think, 44 inches per annum.

3470. What distance is that from your gathering ground?—That is within two or three miles of the point to which I have referred as being about a mile and a half below Rhayader, but then the elevation there is very small, comparatively speaking, and the consequence is that the rainfall must be very much less there than it would be in the watershed to which I have referred.

3471. (*Mr. Harrison.*) Is the level of the river there about 625 feet above the level of the sea?—It is; the level of the reservoir is 590 feet above the level of the sea.

3472. (*Sir J. Thwaites.*) The railway which you see on the map seems to run parallel with the river?—Yes, and it crosses the river.

3473. (*Mr. Harrison.*) Is this a railway that you have made, or is it one of Mr. Robertson's lines?—It is the Mid Wales line; Mr. Piercey's line.

3474. (*Sir J. Thwaites.*) How will that railway be affected by your storing ground?—In no way.

3475. There is an embankment of 75 feet marked upon the map, what embankment is that?—That applies to the reservoir coloured red.

3476. Is it in a valley?—Yes, the land is steep on both sides.

3477. Do you propose to dam the valley?—Yes, I propose to make the reservoir by placing a dam across the valley 75 feet high.

3478. What width would your dam be at the top?—About 12 feet.

3479. I suppose it would be constructed in the ordinary way with a centre of clay puddle ?—Yes.

3480. What do you construct the other part with ?—The slopes would be faced with stone where it was exposed to the wash of the water, but on the other side of the embankment it would be simply a slope.

3481. I suppose you would have a slope on both sides ?—Yes.

3482. To what extent ?—On one side it would slope about two to one, and on the other side I should say about four to one.

3483. Do you think that would be sufficient to resist a pressure of 75 feet ?—Yes.

3484. (*Mr. Harrison.*) You say that at the rain gauge at Rhayader the actual rainfall by the returns is something about 44 inches ?—Yes.

3485. That being so, on what basis do you calculate that there would be 60 inches in area No. 1 ?—Because you will observe the watershed is very greatly elevated. This is the ridge of the hill, and you will find a number of levels marked which show the heights above the sea, and there is the mountain of Plynlimmon which is of the height of 2,467 feet.

3486. (*Sir J. Thwaites.*) You have to make up the deficiency of 20 inches, so that you must have a very large rainfall indeed upon some of those higher parts ?—Yes, so it would be. My opinion is that the rainfall, taking the minimum on those ridges, would be 60 inches, and therefore if I deduct 30 inches for evaporation and absorption, I consider that that is a very safe amount to calculate upon.

3487. If I understand you rightly your calculation is based upon a given rainfall of 60 inches over the whole of that area, but if in part of No. 1 area the rainfall is 44 inches only, you must have a very large rainfall in the other parts of the district ?—But I allow a large margin I consider in the 30 inches.

3488. (*Mr. Harrison.*) Is there not a rain-gauge at Llanidloes ?—Yes, but that is not at any higher level than the one at Rhayader.

3489. What was the rainfall of that gauge ?—It was about the same as at Rhayader.

3490. Then with regard to the rainfall the only guide over the whole of this district that you have embraced in your scheme is practically the Rhayader gauge ?—That is the only point that I am aware of at which a rain gauge has been kept.

3491. (*Sir J. Thwaites.*) Your deduction is that if there is 76 inches of fall in the Lake district, you are safe in taking 60 inches as the fall in this area, which you have described as No. 1 ?—Yes.

3492. (*Mr. Prestwich.*) That would be for a mean of how many years ?—That would be the minimum of the driest year. I am not speaking of the minimum of the Lake district, but of the minimum of this Welsh district.

3493. But you take the Lake district as one point of comparison, and you say that the Lake district is a very rainy district, and that this will follow in a somewhat similar ratio, but in the Lake district there are years when the fall is below 60 inches ?—Yes, that may be so.

3494. Therefore you would hardly place that district on a level with the Lake district ?—I do not see why it should not be so. There are the same causes operating here that are operating in the Lake district. I do not see that there should be any difference. The absorption must be very much the same, because the character of the soil is the same, and the evaporation must be the same.

3495. (*Sir J. Thwaites.*) The question now is the amount of rainfall, because that is the foundation of all your calculations; you really have no data as to the amount of water that would be produced in that area ?—There are no rain gauge observations.

3496. You assume, of course, that if the gauges had been placed at other parts of the district you would have had very much larger results than you have at Rhaiader ?—Yes.

3497. (*Mr. Prestwich.*) Would you not consider it to assimilate more to the rainfall in Mr. Bateman's district ?—I should think it must be precisely the same, because it is so very near it. I have another map (*producing the same*) which will show the relative position of my district and Mr. Bateman's. The Severn scheme district is coloured brown.

3498. (*Sir J. Thwaites.*) In fact you are only separated by a ridge ?—Yes, only by a ridge. I may say that if I were to take the same amount of absorption and evaporation which is allowed for the Severn scheme, which is 12 inches, the quantity which I have stated would be arrived at by a rainfall of 42 inches instead of 60 inches.

3499. (*Mr. Harrison.*) Your calculation is that the districts Nos. 1 and 2 would yield 243,000,000 gallons a day, and Nos. 3 and 4 would yield 150,000,000 ?—Yes.

3500. And that the four districts together would be about 393,000,000 gallons ?—Yes.

3501. On the assumption that you have a net available quantity of 30 inches ?—Quite so.

3502. Have you at all turned your attention to the possibility of a portion, and the largest portion of any aqueduct to London being made available for the district suggested by Mr. Bateman and by your own scheme ?—Yes.

3503. You apparently cross each other ?—Yes.

3504. Where ?—The point appears to be near Bromsgrove. I do not know that I have Mr. Bateman's plan correctly laid down on this map, but it is near Bromsgrove. If the levels of the aqueducts could be made to accord at Bromsgrove, they could run together from that point to London.

3505. Even taking that view of it, assuming that your calculations of the rainfall were erroneous, and that they were not half of what you calculated, the two systems together would be able to supply beyond any question all that could be wanted ?—I should think there could be no doubt that they would supply far more than could be wanted.

3506. And that involves, of course, the question of cost ?—Quite so.

3507. (*Mr. Prestwich.*) Have you gauged any of the streams so as to check the rainfall ?—I have not done so for this reason, that in a river like the Wye the fall is so rapid that it would be a most difficult thing to tell when the proper time would arrive for taking the gauging, and I do not think that the result would be any criterion as to the quantity of water which the watershed would yield.

3508. (*Sir J. Thwaites.*) Starting from your gathering ground, how many reservoirs do you propose to form on the ground ?—I have only dealt at present with No. 1 area as far as regards the provision of reservoirs. The number which I propose there are six.

3509. What would be your storing power in those six reservoirs ?—The quantity which those reservoirs would be capable of storing would amount to 26,000,000,000 gallons, which would be equal as I consider to 150 days' supply.

3510. What do you calculate the necessary supply for the metropolis to be ?—I have assumed 130,000,000 gallons a day, but the present consumption of London I believe is about 90,000,000.

3511. How many gallons per head per diem ?—About 30 gallons.

3512. That includes the supply for all purposes, does it not ?—Yes, for all purposes. I think that is about the average of what London at present requires.

3513. Then No. 1 area would be equal to the present requirements of the metropolis ?—It would be equal to 130,000,000 gallons, which according to the present supply would be about 40,000,000 gallons in excess.

3514. Now will you please to follow on the description of your scheme ?—The reason why I have chosen the Wye district in preference to any other is, that the importance of the navigation of the Wye is very small, and consequently the abstraction of its water would be no injury as far as the navigation is concerned. Indeed from the sea up to Hereford, which

H. H. Fulton, Esq.

16 May 1867.

is the largest town in the district, and which has a population of between 15,000 and 16,000 inhabitants only, I believe the trade is nearly extinguished on the river, that is to say, it is nearly superseded by the railway, and the only trade by navigation which exists now is by the canal from the Severn, which runs up to Hereford.

3515. Would the equalization of the floods cause the mouth of the river to silt up at all in point of scour?—I think that the abstraction of that large quantity of water from that watershed might certainly affect the navigation.

3516. And the effect of the scour of the floods would be neutralized by your principle of compensation?—I do not think it would. I think that a certain amount of injury would arise to the navigation by the abstraction of this large quantity of water from the watershed.

3517. You state, do you not, that there are several flour mills on that stream?—Very few, I believe.

3518. Is the water power there utilized at all for other purposes than grinding corn?—No, I am not aware of any. Below the point where I take the water there are no mills, I believe, whatever.

3519. Now will you describe the course which you propose to take from your reservoir?—The point from which I propose to take the water, as I before stated, is about a mile and a half below Rhayader. At that point the conduit would commence, and go along the eastern side of the valley of the Wye to a point on the river Ithon, where another reservoir could be constructed of considerable capacity. From that point the conduit would be continued to the north-east of Builth.

3520. (*Mr. Prestwich.*) What height above the sea would the reservoirs be?—The upper reservoir would be 590 feet, the lower one would be about 512 feet on the river Ithon, and from that point the conduit would continue along the valley of the Wye, past Glasbury and Hay to the north of those towns, and from thence somewhat to the south of Kington, to the south of Ludlow, to the north of Tenbury, to the south of Bewdley, to the north of Stourport, to the north of Bromsgrove, near to Henley-in-Arden, Warwick, and Banbury, to the north east of Bicester, to the north of Aylesbury, Tring, Berkhampstead, and Watford, to a point near to Totteridge near Barnet, where I propose to construct a service reservoir.

3521. (*Sir J. Thwaites.*) At what height above high water?—It would be at the level of 276 feet above Ordnance datum.

3522. (*Mr. Harrison.*) How far from the Marble Arch?—In a direct line from the Marble Arch it would be eight miles.

3523. (*Sir J. Thwaites.*) What would be the size of your tunnel or aqueduct?—It would be 15 feet wide and 14 feet 6 inches high.

3524. What fall do you give?—The fall would vary from six inches per mile to two feet per mile.

3525. What is the discharging capacity?—It would be equal to a delivery of 230,000,000 gallons a day. Of course the delivery depends entirely upon the velocity, and that I think can be regulated.

3526. Do you give a uniform fall, or do you propose to check it by weirs?—Wherever it was found necessary to do so it would be checked by penstocks and over falls. This section (*producing a section*) shows the section of the country through which the line passes; it is of course only an approximate section. I do not pretend to say that it is correct in detail.

3527. I presume that you must have iron pipes?—Yes, where the valleys are deep.

3528. Do you propose to go through the valleys by means of syphons?—No, in ordinary cases the valleys would be crossed by embankments. The Severn is crossed near Bewdley, and there of course the water would be taken across by a syphon.

3529. (*Mr. Harrison.*) How has that section been prepared?—The section, so far as the end nearest the watershed is concerned to which I have referred, is taken from actual levels.

3530. How far from actual levels?—I should say seven or eight miles, and the rest is made from the Ordnance levels and from the sections of railways and canals, from which I have been able to compile this section. There is a total available fall from the watershed No. 1. to London of 314 feet. Of course the arrangement of the inclines would depend as I said before upon how the permanent section may turn out.

3531. (*Sir J. Thwaites.*) Have you made any estimate of the cost of the scheme as a whole?—I have made an approximate estimate of the cost of the first 130,000,000 gallons which amounts to 7,000,000*l.*

3532. What does that include?—It includes all the works from the reservoirs to the service reservoir, and the connexion with the existing system of pipes in London, including the reservoir at Totteridge.

3533. Of course you have made this section as you state from levels of canals or railways as you could best collect information?—Yes, and from the Ordnance surveys.

3534. Your estimate therefore must be an approximate estimate?—Of course. To make a permanent survey of the whole matter would require a very large expenditure, and occupy a considerable amount of time.

3535. Have you made this estimate, such as it is, from the materials at your disposal a full estimate?—I think it is ample.

3536. I understand that the 7,000,000*l.* sterling includes all the cost of the gathering ground, the formation of the reservoirs, your aqueduct, tunnels, the service reservoir at Totteridge, and the connexion with the London system of distribution?—I do not of course propose to pay any compensation for the gathering ground, because that gathering ground would not be interfered with in any shape or way.

3537. You simply purchase that which you will occupy by the reservoirs?—That is all.

3538. You do purchase that?—Yes, certainly.

3539. Have you made any calculation as to the compensation to the millowners and other parties on the stream of water of which you intercept?—The millowners would be compensated by water and not by money.

3540. Have you not estimated any money compensation to any party on the Wye?—Only in cases where they would be interfered with by the reservoirs. If the sites of their mills were interfered with by the reservoirs, of course they would require compensation.

3541. With regard to those lead mines within your gathering area, do you propose to purchase the interest in them, or how are you to deal with their washings?—Anything that was likely to pollute the water I should propose to divert from the reservoirs.

3542. And have you estimated the probable cost of that?—Yes, and I have included that in the 7,000,000*l.*

3543. How many miles long is your tunnel?—180 miles is the whole length of the conduit.

3544. (*Mr. Prestwich.*) How many miles would be tunnel?—The covered portion of it would be 60 miles, and the tunnelling portion would be 18½ miles.

3545. (*Sir J. Thwaites.*) Does your estimate include compensation for easement in places where you occupy the surface?—Yes, of course, in cases of this sort I have put down a lump sum which I consider sufficient to cover everything.

3546. Have you had regard to the question of compensation for easement and for actual purchase and for severance?—Yes, all that is assumed to be included in my estimate.

3547. (*Col. Harness.*) What guided you as to covering the portions of the channel that are not in tunnel?—The nature of the soil to a great extent.

3548. You make a culvert of it altogether do you not?—For portion of the line I do.

3549. Have you covered any portion of it that is not a culvert?—Yes, the distinction between the covered portion and the tunnel is simply that the one

H. H. Fulton, Esq.

16 May 1867.

is cut open and covered again, and the tunnel of course would be in tunnel, it would not be an open cutting; as regards the shape of the culvert that would be the same in both cases.

3550. Why have you covered it in the portions that are to be made open cutting?—Because it is desirable to do so where it approaches thickly populated districts, where the water would be liable to be polluted.

3551. (*Sir J. Thwaites.*) How do you intercept from your channel the surface water and the drainage from land under cultivation, polluted by manures; have you any arrangement for that purpose?—There would be no water draining into the conduit in any case from cultivated lands.

3552. I suppose, as a principle, you exclude all drainage from the water?—Yes, all drainage would pass through the present channels. Wherever a drain was crossed, of course the drainage must be provided for by a culvert, and not be in any way interfered with.

3553. What time do you think it would occupy to complete this scheme after parliamentary powers were obtained?—I do not see any reason why it should not be completed in the course of five or six years. I do not think that the heaviest portion of the work would require a longer period than that.

3554. (*Mr. Harrison.*) Of course the heaviest embankment of your reservoirs would be the measure of the time?—Yes. If they were properly made the consolidation would be very small indeed.

3555. (*Mr. Prestwich.*) With regard to the work itself, you have stated that there is to be 18½ miles of tunnelling and 91 miles of cutting; what is the remainder?—The lengths that I gave were these: the length of the open portions was 91 miles 13 chains, the covered portion was 60 miles, the tunnel was 18½ miles, and the inverted syphons 10 miles 27 chains, making a total of 180 miles. Of course that is only an approximate calculation, as I said before, and the measurements could only be properly arrived at by a more thorough survey.

3556. (*Mr. Harrison.*) Do you propose to put your estimate in?—Yes, I will supply it to the Commission.

3557. I think I understood you to say that the sites of all your reservoirs have been actually levelled?—Yes, they have.

3558. Have you ascertained what the nature of the strata would be upon which your embankments would be made?—Principally rock and clay. I think that in every instance there is clay as regards those reservoirs which I have shown the Commission upon the plan.

3559. Have you had sections also taken of the areas of those reservoirs, from which to calculate their capacity?—Yes, I have.

3560. Have you also a section of the open conduit?—Yes (*producing the same*). The open portion would be 36 feet wide at the top and 18 feet at the bottom, with slopes of 1½ to 1, the depth being 6 feet. Of course that cross section would be modified according to the fall that would be found necessary.

3561. Do you propose to line it throughout from end to end?—Yes, I propose to line it either with puddle or with concrete. Of course, where concrete was used it would be a different section altogether, and if it were through clay the puddling would be unnecessary.

3562. Would you trust to an aqueduct of this nature without any lining at all except merely the puddling?—Where it was solid clay, I should think that lining would be unnecessary. Of course I mean that instances of this kind would occur.

3563. You assume, do you not, a fall of one foot per mile?—Yes.

3564. Then in that you would have penstocks, of course, to regulate the flow?—Yes.

3565. (*Col. Harness.*) What velocity do you allow in this open cut?—A velocity of 157 feet per minute.

3566. That is unchecked by penstocks?—Yes, that is with a fall of one foot per mile. It would depend very much upon the curves which might exist upon the line of the cut.

3567. (*Mr. Harrison.*) You would hardly, perhaps, give a fall of a foot per mile through that open conduit through clay without its being lined?—Not unless it was checked by penstocks, I think.

3568. No doubt you have abundance of fall, and you could give a greater fall where you cross the valleys, if it is desirable?—Quite so.

3569. The only question would be the estimate, if it were found necessary to line your conduit throughout?—Wherever the fall exceeded a certain inclination, I should think it desirable to line the cut.

3570. But your estimate of 7,000,000*l.* is not made upon the assumption of lining your conduit?—It assumes it to be lined throughout where the inclination exceeds a certain limit.

3571. What is that limit?—I should say about 4 inches per mile.

The witness withdrew.

Adjourned to Thursday next at 11 o'clock.

Thursday, 23rd May 1867.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND, K.G., IN THE CHAIR.

Sir JOHN THWAITES.
Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.
THOMAS ELLIOT HARRISON, Esq
JOSEPH PRESTWICH, Esq.

Capt. EDWARD BURSTAL, R.N., examined.

Capt. E. Burstal, R.N.

23 May 1867.

3572. (*Chairman.*) Are you the Secretary of the Thames Conservancy Board?—I am.

3573. You have been for a great number of years connected with the River Thames, have you not?—A great many years.

3574. How many years?—I have been nearly 10 years Secretary to the Conservancy Board, and for many years before that I was connected with the Thames, and having made surveys of the river for the Government on and off many times since 1833.

3575. You are therefore well acquainted with the River Thames and all its tributaries?—Yes.

3576. And with the whole of the district through which it passes?—Yes.

3577. Will you tell us briefly what are the duties of the Thames Conservancy Board, especially with reference to the new Act?—The Thames Conservancy Board under the powers conferred upon them by the Act of last year are empowered to keep the river in order both for the purposes of navigation and for the purposes of keeping the water in a pure state for the metropolis for drinking purposes.

3578. (*Col. Harness.*) Between what points?—Between Cricklade westward and Staines eastward by the last Act, and by the former Acts from Staines westward to Yantlett near Southend eastward.

3579. (*Chairman.*) In fact you go from Cricklade to Southend?—Yes, to Yantlett near Southend.

Capt. E. Burstal, R.N.

23 May 1867.

3580. (*Sir B. Phillips.*) Is that the extent of your jurisdiction?—Yes.

3581. (*Col. Harness.*) Does your jurisdiction include the tributaries of the Thames?—The jurisdiction of the Conservators does not extend up the tributaries for navigation purposes, but only for the purpose of keeping the water pure, and that jurisdiction extends three miles in a straight line from any part of the river where those tributaries may flow into it.

3582. (*Chairman.*) Will you tell us what powers you have for keeping the Thames water pure, and how you practically exercise them?—There are clauses in the Act of Parliament which empower the Conservators to prosecute any persons who may throw or allow to flow into the river any impurities whatever; and the Conservators have ever since they have been in office encouraged informers to come to them and give them every information as to persons who allow filth to flow into the river, or throw it into the river; and they have taken proceedings innumerable almost against persons who have committed this breach of the law, and they pay rewards (generally speaking they are rewards of 40*s.*) to informers who get convictions for those offences. With regard to the upper part of the river which has lately come within the jurisdiction of the Conservators, what the Board have done has been to give orders to all the lock-keepers to collect all refuse and deleterious matters which shall accumulate at the weirs. They have supplied them with rakes and so on, and whenever any dead animals or refuse of a foul character collects at those points those lock-keepers get them out, and dig a hole in the towing-path and bury them. In addition to that the Board have ordered a little craft, a sort of screw tug, to be built, and she is just completed at Bristol; and on board that vessel will be men whose duty will be to inspect the river, and whenever on their passage from Oxford downwards, or in any part of the district where they go, they meet dead animals or any other refuse of an improper character, to rake it out of the river and bury it at once. This has been done to a very considerable extent already, but it will be done we hope in a perfect manner when this little vessel comes into work, which will be in the course of a fortnight or three weeks.

3583. What do you do as regards sewage and matters of that kind?—What the Board have done with regard to sewage has been this, they have complied with the requirements of the Act in giving notices to all the towns on the river to discontinue the discharge of their sewage into the Thames.

3584. Does the Act apply to particular towns, or to towns of a particular size?—It applies to every town, or every person in fact who ejects sewage into the river as far as that goes, but what the Board have done has been to issue notices to the town councils, and boards of health, and sewage authorities of the various towns, such as Oxford, Abingdon, Marlow, Reading, Windsor, and other places which I do not remember at the moment. Those notices have been served requiring them to discontinue discharging the sewage of those towns into the river within a period of 13 months.

3585. Has that time expired?—No, the notices have only been issued about three weeks or a month.

3586. What will be the course that will be taken by those towns?—It is very difficult to answer that question, because of course it remains with them to decide as to how they will dispose of their sewage. Whether it will be by settling tanks, and then the water percolating through a material which will render it innocuous, it is difficult for me to say, but it is a question more for the engineer to decide than it will be for me.

3587. Putting it in the other way, in the event of their not complying with your orders, what course do you take then; supposing you find that the sewage at Windsor for instance is allowed still to go into the river instead of being kept out of the river, what would be the course taken by the Board?—The Act of Parliament provides that they shall be fined 100*l.* at once, and 50*l.* a day for every day they neglect to do it after the time of notice has expired.

3588. Is that fine to be inflicted upon application to the magistrate, or who puts the law into force?—I rather think it is; I am not quite sure whether it is the petty sessions or not.

3589. Do you believe from your knowledge of the river, and the towns upon the river that the powers of that Act are sufficient, and that you will be enabled to keep the river pure from those pollutions by means of that Act?—I think to a very great extent we shall.

3590. Assuming that the water which now flows into the Thames from those various places is of necessity impure from the drainage of the towns which are upon the river, and the various impurities which come into the river at different parts, do you think that by means of this Act you will be enabled to say that the water of the Thames shall in future be pure?—I think whatever steps are taken with the view of altering the system of drainage, instead of allowing the drainage to go into the river as it does at present thick and thin, by adopting a means of draining it into large tanks and allowing it to percolate into the river in a limpid form instead of being in a turbid state as it is now, the waters will be deprived of a very large quantity of the organic matter which exists in it at present, and therefore, of course, the sewage in that form will be very much less pernicious than the sewage which flows in at present.

3591. (*Col. Harness.*) But there will still be a flow of the residue of the sewage into the water?—Not provided they adopt that system; I cannot tell that they will adopt it. If, however, such a system should be adopted there would be a flow of material into the river which would be charged with a certain proportion, but at present the Board are not authorized to recognize any such thing.

3592. Have you any power to stop such a flow?—Excepting by the notices which I have referred to; those would stop it, I presume.

3593. (*Chairman.*) You will have the power under the Act of bringing offenders before a magistrate and complaining that they allowed any portion of their sewage to come into the river?—Yes, and upon that being proved would be fined.

3594. (*Col. Harness.*) If the sewage were collected in tanks not far from the river, and the material between were such that it could percolate through, could you prevent that?—I really think so, if that material was found to be deleterious.

3595. What is the title of the Act to which you refer?—It is the Thames Navigation Act of 1866.

3596. (*Sir. B. Phillips.*) What is the constitution of the Board of the Thames Conservancy?—The constitution of the Board is the Lord Mayor of London, two of the Aldermen, four of the Common Council, two members sent by the Admiralty, two members sent by the Board of Trade, and two from the Trinity House, and there are two representatives of ship owners, two of lightermen and barge owners, one representative of dock owners and wharfingers, one representative of owners of passenger steamers, and four members elected under the Act of last year for the upper district, making 23 in number, I think.

3597. Has that Act been put in force with regard to the election of the four last members you have mentioned?—Yes, those members have been elected.

3598. What are they?—They are land owners; one of them is a miller, and has mill property on the river. Mr. Clutterbuck, the clergyman, who has been examined before this Commission, is one, Mr. Harcourt is another, and Mr. Hedges another.

3599. Do you know what quantity of water the existing companies are allowed to draw from the Thames for their daily supplies?—According to the arrangement made with the corporation of London in 1852 the limit is 20,000,000 gallons a day each of them.

3600. How many companies are there?—Five companies.

3601. Have you ever considered what additional quantity could be drawn from the Thames?—An enormous quantity more than is drawn already without the river feeling it above Teddington Lock to any great extent.

3602. (*Chairman.*) You say that they have the power to draw 100,000,000 gallons per diem from the river, can you tell me what quantity they absolutely draw now?—Yes, I can, because we have a monthly report from each of the water companies sent to me of the average quantity during the month per diem, and it comes out in this way, that on the average for the last four months the Chelsea Waterworks Company have taken 7,500,000 gallons a day, the Grand Junction 8,700,000 gallons, the Lambeth 8,500,000 gallons, the West Middlesex 8,400,000 gallons. The Southwark and Vauxhall have made no return, but assuming the Southwark and Vauxhall to be 8,500,000, which is rather more than the average of the others, that will make the average per day for each of the companies 8,300,000 gallons.

3603. Do you consider those five months a fair test? are they the water consuming months?—No; those have been the winter months. I think in fairness we should put perhaps 25 per cent. on to that quantity for a fair average for six months.

3604. If you were to call the six summer months 9,000,000 per company, do you think that that would be within the mark?—Yes, I should think it would be so, taking it for nine months of the year.

3605. (*Col. Harness.*) Then they really do not draw more than half their supply?—They do not draw one half. I think the water companies consider that in round numbers they draw about 8,000,000 gallons a day each of them through the year. I think it would be a little more than that as those figures would show.

3606. (*Chairman.*) And they are entitled to take 20,000,000 gallons each?—Yes, they are entitled to take 20,000,000 gallons each by the agreement made with the corporation in 1852.

3607. Can you state whether the quantity that they take diminishes in any appreciable degree the quantity of water in the Thames?—We do not observe it at all. We have never found the water fall short of flowing over Teddington lock.

3608. Is Teddington lock a sort of test?—Teddington lock is the last lock, where the water passes over the tumbling bay at Teddington lock, and there has never been any diminution to any appreciable amount in the flow of water over Teddington lock. That is what is stated by the lock-keeper, who has been there for many years.

3609. Would that apply to the driest season that we have had the last 20 years?—I do not exactly know that, because I think that the failing of the water below Teddington lock has been attributable to a great extent to abstracting the water from the river above, and thus get less water to run down from Teddington to Richmond; and I do not think from the observations which were made in 1821, compared with the observations which have been made within the last few years, that there is more than two or three inches vertical difference in the average height of the water at summer levels at Richmond now compared with what it was then.

3610. (*Sir B. Phillips.*) You say that they only draw at present about one half what they are permitted to draw; supposing they took the whole of 100,000,000 gallons per diem, what effect would that have upon the river?—I have no doubt that the water would sink below Teddington lock, or taking Richmond as a point the water would subside to some extent, but not very much.

3611. Not in any way to impede the navigation?—No, the navigation is not affected there by the land water so much as it is by the tide water. All the navigation of the river from Teddington lock down to Putney is a navigation contingent entirely upon the tide and not upon the land water at all, or scarcely so.

3612. Supposing it were necessary to draw a very much larger quantity from the Thames for the supply of London, could the supply above that district be in any way increased by the tributaries at present in existence?—What I have thought is this, that supposing it to be in practice considered necessary to husband the water of the Thames I think it might be done in a very effective way by making reservoirs in the upper district probably, before you come to the populous towns, such as Oxford; say seven miles above Oxford.

3613. (*Chairman.*) Have you turned your attention to the possibility of making one or more reservoirs, and if so, in what district do you propose to make them?—I have heard this subject discussed by some engineers, by our own engineer, and by Mr. Beardmore also, and it appears to me that reservoirs could be made about 7 miles above Oxford near Ensham of a very large and capacious character, to store during the wet weather an enormous quantity of water which would never be missed in weather of that sort in Oxford; in fact they would be rather glad to get rid of it, as it would prevent some of their low-lying districts from being flooded, and that storage could be made so as to supply any deficiency that might occur in the lower part of the river. What I mean by the lower part of the river is the part near Hampton where the present pumping stations of the water companies are.

3614. And that would be a supply to meet the emergency of a very dry year?—I should think it would be only required in a very great emergency, in very dry weather; but in the ordinary state of the river, in its normal state the river is capable of supplying a very much larger quantity than is already taken from it. The reason why I have come to such a conclusion is that when the Colne Water Bill was before the House, some years ago (I think it was as far back as 1860, although I am not quite sure of the year) the Conservators were desirous of getting the opinion of the celebrated engineer, the late Mr. James Walker, they were not quite sure in their own minds whether if an abstraction of 10,000,000 gallons per diem was made at that part of the river which is near Staines, where the Colne flows into the river Thames, it would not be inimical to the navigation, and Mr. Walker told us that if the evidence that he could give would be of any assistance he would readily give it, but that it would certainly be to this effect that it would not be more than the thickness of a sheet of paper over the surface of the river below the point of abstraction.

3615. Then you probably did not call him as a witness?—No; the Board considered that with such an opinion as that from such an eminent engineer, the thing was not of sufficient importance for them to oppose the Bill.

3616. Are you able to give the Commission any opinion as to the quality of the water which is supplied to London?—I have not turned my attention much to that subject. I have read the tables of comparison between the water that is supplied from the Thames and that from other sources.

3617. Have the Board to which you are secretary had any complaints made to them of the quality of the water supplied to London?—No, we have never had any complaints of that kind at all.

3618. Probably they would not be the proper body to go to?—I should think after the Act of 1866 the province of the Board being to keep impurities from the water, most likely if there were a ground of complaint that complaint would be sent to the Board, but at present we have had no complaint whatever.

3619. But that Act would hardly have been a sufficient time in operation, in fact your powers have not been exercised?—I think not. We have scarcely got into harness, one may say.

3620. (*Mr. Harrison.*) According to your observations, is the head of the river now lower than it used to be in your recollection, taking it at Hampton?—No, I think not at Hampton, that is above Teddington lock.

Capt. E. Burstal, R.N.

23 May 1867.

3621. Is it at Wandsworth?—Yes, it is at Wandsworth. I was employed by the First Commissioner of Works in 1856 and 1857 to make a survey of the river, and I made a very minute survey and I reduced all the bed of the river in the same manner as an engineer would reduce any other valley, and I compared the levels with the levels taken in 1821 and I found there that the water had subsided, that the low-water surface of the river was lower in 1856 and 1857 than it was in 1821.

3622. To what extent?—I think it was nearly two feet lower at Putney than it was formerly, but that is only at one particular point. If you take it up to Richmond and so on you would find it less, and at Teddington less again, and so on, it just depends upon what part of the river it is, but I made out some tables which I lent Mr. Harrison, which would tell exactly what the difference was.

3623. (*Col. Harness.*) That would be before the removal of the old London Bridge, would it not?—The observation made in 1821 was of course before the removal of old London Bridge. My observations made in 1856 were after, and in my report to Parliament which I delivered to Sir Benjamin Hall, who was then the First Commissioner of Works, the report of February 1857, you will observe my remarks on the exact state of the river at that time as compared with the state of the river before, and also my reasons why I thought such should be the case.

3624. Have you any records of the changes which have taken place since?—We have records in our office, but they have not been of such a magnitude or anything like such a magnitude in proportion in the last 10 years as they were for those 20 or 30 years before.

3625. (*Mr. Harrison.*) Is it a fact that within the last 10 or 15 years, the low-water surface of the river has lowered?—Yes, it is so.

3626. That is principally owing, is it not, to the improvements which have been making in the river down below, and the dredging works which you have been carrying on lower down?—No doubt. But I should like the Commission perfectly to understand that the improvements which have been made below London Bridge can have had no effect whatever upon that. If you study the tidal wave of the river with diagrams drawn from it, you will certainly come to the conclusion that whatever dredging you do below London Bridge can never affect the river in the western part of it. The great changes which have taken place have no doubt to my mind been consequent upon the removal of old London Bridge, and then since that there has been the removal of Westminster Bridge, and since that again there has been the removal of certain shoals which were visible every day below Westminster Bridge and Waterloo Bridge. All those banks which showed above water at low water acted as dams to not only the tidal water but to the actual river water, and the removal of those things has no doubt to my mind, caused a considerable portion of the up-river water to escape and thereby reduced the low-water surface in all points of the river to the westward.

3627. Taking that to be so, it is quite obvious, is it not, that the navigation up to Teddington must depend a great deal more now upon the tidal water than it used to do formerly?—Yes, in one way it does, but generally speaking, it does not, and I will endeavour to explain that. The navigation is still in fact all the way up to Putney, as it always has been; barges, and so on, get up to Putney at low water, if they have a fair wind, and can sail against the stream, there they have towing horses—they are nearly all towed by horses—the towing-path commences there, and they now, as they always did before, tow when the flood makes (and the navigation is during tide time), and they have got just as much time and just as good a navigation from Putney to Teddington now as they always had on the flood tide, but where the navigation has suffered to some little extent has been on the ebb tide. In consequence of the removal of the obstructions which I have just referred to on the receding of the tide the ebb runs off more quickly than it did formerly, and the consequence is that barges and craft which used to be able to hang on at Teddington and that neighbourhood for perhaps two hours or two and a half hours after high water are now obliged to be off and get away as soon as they can after high water, or else they are caught from the water draining off more quickly.

3628. We have had it in evidence that the minimum quantity of matter ever passing over Teddington lock would be something like 350,000,000 gallons a day, can you confirm that statement?—That is exactly the quantity that I have got. The lowest quantity that we know over Teddington weir is 350,000,000 gallons per day in dry summer weather—that is, of course, after the present water companies have abstracted their water.

3629. Which would make it something like 400,000,000 gallons?—Yes.

3630. Did you ever hear that on some particular day that quantity came down to 305,000,000 gallons?—No, I have not, and I have asked our engineer whether he has ever taken sufficient gaugings, and he says that Teddington weir, from not being quite so level as it might be for gauging purposes, it is rather difficult to get such good gaugings over the top of that weir as would give very correct estimates.

3631. Your Conservancy Board are going to make Teddington lock into a gauge, are they not?—I have heard that it is proposed to make the weir at Teddington of such a character as to enable proper gaugings to be taken in it.

3632. Have not the present water companies under the Act of last session to contribute each 1,000*l.* a year towards the Conservancy?—Yes, they have, making 5,000*l.* altogether.

3633. And you have an absolute power under that Act to exclude all direct drainage into the Thames of every sort and kind?—Yes.

3634. Is there any provision as to the way in which that is to be met by the towns?—No, there is not. That is left to them to manage themselves.

3635. Have you the power of seeing that when it does come into the Thames it has either been used on the land, or that it is purified?—Yes, certainly.

3636. What is to be the measure of that purification?—As I said before that purification and the manner in which it is to be purified must be left to the towns themselves and their engineers. If they settled the sewage in tanks and let it run off when it was foul, the Board would oppose it and would not allow it.

3637. Do you know whether you have any special power by your Act as to testing the extent of that purification?—No; but I should think that if any fluid ran into the river, what the Board would do would be this: they would cause it to be analysed, and if it was of an improper character after that they would insist upon its being stopped. I should think there is no doubt about our having that power.

3638. I suppose that the question of forming reservoirs in the Thames is one to which you have had your attention directed?—Yes; it has often been spoken of in case of any necessity, and the water companies, I believe, have rather anticipated that.

3639. From your knowledge of the Thames you do not anticipate any difficulty on that point?—No; I have been from Oxford all the way down the river three times within the last two months, and there is an enormous quantity of water in the river now.

3640. (*Sir J. Thwaites.*) With regard to the power of the Commissioners under the Act of last session you have already given evidence?—Yes.

3641. The local authorities will have to deal with their sewage?—Yes, I presume so.

3642. Either by deodorization or utilization?—Yes; they must deal with it or interfere with it in the best manner they can; whether it comes into the river in a pure state is for their consideration.

3643. Have you power under the recent Act to

stop the discharge of the water that may be the result of settling tanks; supposing, for example, that one of the local authorities should elect as the cheapest process the running of all their sewage into a series of tanks and allowing the water to run off, and dealing with the solid matter precipitate, have you power under that Act to prohibit the discharge of that water into the Thames?—No; I should think not if that water was rendered innocuous, and if on analysis it turned out to be completely free from organic matter.

3644. That should not be so, because you would have held in solution all the most poisonous properties?—If that were the case the Board would object to it, no doubt.

3645. Have you power under that Act to prevent that?—Yes, I should think so. I think it is quite clear that if that fluid after having escaped the settling tanks came into the river in a noxious state and charged with organic matter, the powers granted to the Board would be quite sufficient to prevent its flowing into the river.

3646. Do you know at all the views of the local authorities with regard to this question?—I think that some of the local authorities are rather glad that some steps have been taken; others are puzzled very much to know what to do with it. There is no doubt that it must be a difficult question.

3647. What is the date when they must take steps?—Not less than 12 months from the date of the notices being given, and then if difficulties arise in their mind they can apply to the board to have an extension, such extension not to exceed three years.

3648. Would the first action be a notice by the Conservancy Board to the local authorities that on and after a certain date any discharge of sewage into the Thames should be prohibited and subject the parties to penalties?—Yes, those notices have been issued, that on and after the date of the 13 months from the service of the notice they are to discontinue the notice, stating the Act and the Clause in the Act.

3649. Have you given notice to all the local authorities?—Yes, to all of them.

3650. Beyond the metropolitan area up to the extent of your jurisdiction?—Yes, all up to Oxford inclusive.

3651. Have any of the towns applied for time to make arrangements?—None whatever.

3652. Has the time of your notice expired?—No.

3653. What was the extent of the time given in the notice?—Thirteen months.

3654. You anticipate, I presume, an application for extension of time, because sewage works cannot be carried out in 13 months?—No, I should think not, it is a short time, but still it gives them sufficient time to think over the matter, and if they have got any scheme by which they can get rid of their sewage in another way I have no doubt they will apply to the Board and an extension of time will be given them.

3655. Have you power to deal with the tributaries of the Thames?—Not for navigation purposes, but we have power to deal with all the channels, whatever they may be, within three miles in a straight line from the river Thames, at right angles to the course of the river.

3656. Take the Wandle, for example, have you any power to deal with those paper manufacturers which are on the Wandle?—We gave notice only a short time ago to one paper manufacturer, Mr. McMurray, to discontinue the flow of some matter that was flowing from his mill into the river.

3657. And you have power to deal with that case, have you?—Yes, we can deal with that like any other nuisance, as we have done in hundreds of instances in the river. If Mr. McMurray puts foul stuff into the river, and we found by analysis that it was bad, he would be brought before a magistrate and punished.

3658. It was the infirmity, was it not, of your previous Act that you could not travel up those streams?—No, that power was given in the Act of 1864.

3659. That Act is now amended?—Yes.

3660. You feel that you have now power to protect the Thames from pollution, either through its tributaries or immediately from its banks?—Yes. Our inspectors go up all its tributaries within three miles and trace any foul matter, and if there is anything important they report it to the Board, and notice is given to the parties, in fact no notice is given in a case of that sort, they would be brought up before a magistrate at once as in an ordinary case of nuisance. We have had great numbers of cases of that sort.

3661. I need hardly ask you whether the Board are disposed to put in force those powers to prevent those nuisances?—They have not only a disposition but we have done it, we have given orders to all the lock-keepers to remove all dead animals, and all refuse that accumulates at those points. We generally find that all accumulations of floating stuff, whatever it may be, are arrested at the weirs, and the lock-keepers are supplied with very long rakes of a peculiar construction, and it is their duty to take those things out of the river, dig a hole in the towing-path, and bury them, and they have performed that duty.

3662. Do you know whether Mr. Simpson has made a section of the river just above the point where the Chelsea Waterworks take their water at Hampton?—No; I have not seen any section drawn by Mr. Simpson.

3663. You have no fear as to the abstraction of such an amount of water as may be necessary for the supply of the metropolis, have you?—Not the least fear in the world.

3664. And still less if the principle of storing were adopted?—No fear at all if the principle of storing were adopted at some point above the highest town, which you may, I think, fairly call Oxford, where there are some places where a large amount of storage could be made, and where the fall would be very great downwards, because the river takes a rise up there; and I should think that very large reservoirs, if necessary, could be formed for the storage of water in wet weather.

3665. I suppose that any sewage discharged into the river above Oxford would lose its chemical qualities before it arrived here?—One cannot quite get over the idea that when the water is running down the river at the rate of two or three miles an hour, and then runs over the tumbling bay and gets washed about, it becomes aerated and it loses an enormous quantity of foul matter that is held in suspension.

3666. (*Mr. Harrison.*) If necessary, do you suppose that Parliament would hesitate to extend the powers of your Conservancy Board beyond three miles?—I have no doubt that if Parliament considered it necessary they would do so; but three miles is a pretty long stretch.

3667. (*Sir J Thwaites.*) You have of course observed the condition of the Thames within the metropolitan area?—Yes.

3668. It has improved, has it not, very much all the way up?—Yes, wonderfully; there is no doubt about that. It is quite impossible to express the difference in the character of the water now compared to what it was nine or ten years ago, which is no doubt caused by the taking of the sewage away to another point.

3669. (*Mr. Harrison.*) Mr. Leach is your Acting Engineer, is he not?—Yes, he is.

3670. Has he made many observations extending over any length of time upon the Thames with regard to its flow?—Yes, a great many. We have got observations at every lock as to the height of the water every day, and below the locks we have observations at all the piers as to the state of the tide at high water and low water all the year round for the last seven years.

3671. I mean particularly as to the upper part of the Thames above Teddington?—Yes, he has those; the lock-keepers keep a register every day of the height of the water up there.

3672. (*Col. Harness.*) Is there any upward flow of water at all at Richmond during any period of the tide?—Yes.

Capt. E. Burstal, R.N.

23 May 1867.

3673. Where does that upward flow cease?—At Teddington lock; there is a little stream observable even at Twickenham. You get a stream sometimes at the rate of as much as half or three quarters of a mile up at Twickenham.

3674. Does the tide rise quite to the level of Teddington weir or about the level of Teddington weir?—I do not know the exact level of Teddington weir, but I think it is somewhere about 2 feet 6 inches or 3 feet above Trinity. I do not quite know what it is, but I know that there have been instances in which the tide has flowed over the top of Teddington lock, and really swelled the river at Kingston.

3675. (*Chairman.*) Could Mr. Leach give the Commission in detail the various gaugings of the river which you have mentioned?—I think it is very likely he could.

3676. (*Sir J. Thwaites.*) With regard to the arrangement with the water companies, that in consideration of certain steps being taken to purify the Thames each company should contribute 1,000*l.* a year; supposing any fresh source of water supply were established how would that contract stand as between you and the companies?—If the companies were done away with, and the water companies did not supply London, I suppose they would not pay us the money.

3677. Are they not under a statutory obligation to do so?—Yes, under the Act of 1866 they are, but of course if the water companies are done away with, it is quite clear we cannot get that contribution.

3678. (*Chairman.*) As I understand, they pay you 1,000*l.* a year each for certain things which you do on the river?—Their object is to keep the storage water, and we have to maintain the weirs and locks, all of which tend to keep up the water.

3679. It is for work done, and which is supposed to be for their benefit, that they pay you the 5,000*l.*?—Yes, for doing what we do towards maintaining the purity of the water.

3680. In the event of its being found necessary (supposing the supply of water for the metropolis is obtained from the Thames) to make either one or more very large reservoirs, which might be a very costly undertaking, the same argument would apply to induce them to pay an additional sum for such reservoirs in the same manner as they pay you now for the work done at the weirs?—I should think so, certainly.

3681. (*Sir J. Thwaites.*) Just reverse the question of contract as regards that payment of the water companies, supposing that they were compelled by Parliament to obtain a supply elsewhere, and supposing that Parliament were to make provisions for dealing with that water, what would be the position of your Commission, having certain obligations to discharge in consideration of this payment; would you be prepared to give up that payment and still discharge your obligations?—I cannot say what our Board would do, but, as I said before, if the water companies occupation is done away with, they would not have the means of paying us the 5,000*l.*, and we should have to do the best we could without it.

3682. (*Mr. Harrison.*) You will have to raise a considerable amount of money, will you not, to put your locks and weirs in order?—Yes, it is a very expensive thing indeed.

3683. And that money you will borrow partly on the security of this amount of contribution from the water companies?—Yes, that would be part of the security, no doubt.

3684. (*Sir J. Thwaites.*) The locks all the way up were in a very bad condition, were they not, when you took them in hand?—Very bad indeed; we are repairing some of them now; some of them are very dangerous indeed. We have three in hand at once now, putting new lock gates in. We are going to rebuild Bell weir entirely, and Romney lock entirely.

The witness withdrew.

G. W. Ewens, Esq.

GEORGE WHIFFEN EWENS, Esq., examined.

3685. (*Sir J. Thwaites.*) Are you a civil engineer?—I am not.

3686. What are you?—A merchant.

3687. Do you know anything about the supply of water to the metropolis—have you turned your attention to that subject?—In common with many other scientific subjects, I have studied that question a good deal. Some years ago, from having been brought in contact with the inquiries in reference to cholera, I was led to imagine that the supply of water had a good deal to do with it, and subsequent inquiries led me to seek for other sources than that of the Thames for the supply of the metropolis. My occupation and inclination led me in subsequent years to seek for those sources, and imagining from the tests that I applied to the water supplied by various streams that none of those streams were sufficiently pure for the supply of a great metropolis, I came to the conclusion that the really legitimate source of supply was that of springs, provided that those springs could be discovered that would give a sufficient volume for such a supply. After some years of hunting about I fancied that I had discovered springs of a sufficient volume, and I have had the water analysed by Dr. Hassall; he pronounces it to be exceedingly pure, and I am satisfied that the quantity is quite sufficient to supply the metropolis.

3688. Where are those springs?—The springs themselves are situated six miles south of Goodwood. I am obliged to bring my scheme before the Commission in a very unpretending sort of way.

3689. You stated that you were a merchant?—Yes, my own business is that of a merchant, but in common with a great many other scientific matters, I have looked into this and made a sort of hobby of it. I had the pleasure of forwarding you a report upon the subject.

3690. Where is the point where the springs exist?—The springs extend from Emsworth (about six miles from Goodwood) to Bedhampton in Hampshire, a distance of two miles. By a singular coincidence nearly the whole rainfall upon a large shed of upwards of 50 square miles finds an outlet there. A very large proportion of this watershed is composed of chalk hills and sandy valleys, receiving very little cultivation, sustaining a very small population, and, as a consequence, the water contracts very little contamination from either animal or vegetable organic matter laying on those surfaces.

3691. Will you describe the springs?—I have brought with me a very rough sketch of those springs (*producing a sketch*). These springs rise at Emsworth, Havant, Bedhampton, Brockhampton, and Langbourne, and they throw up enormous bodies of water.

3692. Do they rise out of the chalk?—Although the valley in which these springs take their rise is composed of a very strong clay, I imagine that as the hills above consist of chalk, so the chalk underlies the clay in the valley, and the water may find its way to the surface through fissures of the chalk.

3693. Have you gauged the quantity of water at a point near to Bedhampton mill?—I have repeatedly gauged the waste water from Messrs. Snook's mill, which is driven by the whole supply derived from the Bedhampton springs, and in August 1866 the quantity amounted to about 87,450,000 gallons every 24 hours during the summer of 1864, at which time I resided in the immediate neighbourhood. After an uninterrupted drought of *seven weeks*, the water of the whole of the springs decreased in volume 30 per cent., but not to any greater extent.

3694. Can you put in any result of your testings

for a series of years ?—The variation in the quantum thrown out at various times of the year is so small that I can only account for it by the water having such an ample depth of chalk to percolate through before it comes to the surface.

3695. Have you gauged those springs in every month of the year ?—Not in every month.

3696. Have you a memorandum of the gaugings and the result of each gauging ?—In August 1866 at the time that the water was measured, or at least this estimate was made, it was about the driest season in the whole of that year, and it gave me this result.

3697. Have you any other result ?—With the exception before mentioned, I have gauged it for the last five years repeatedly, at various times of each year, and the result has always come out so very near that the difference was almost imperceptible.

3698. Have you not observed any variation in the flow ?—Only as above stated.

3699. How many mills are there from the point of your gauging to the discharge into the sea ?—There are *six streams* formed by *nine separate* series of springs ; each of these streams flow into the sea at an average distance of half a mile from the spot from whence they take their rise. There are eight flour mills driven by these six streams, and I have generally gauged the waste water at the mill sluices when the mills were not working.

3700. Are they large flour mills ?—Four of them are very large mills.

3701. (*Col. Harness.*) Does the whole stream go through those mills ?—Supposing this and two following questions to refer to the Bedhampton stream, yes.

3702. (*Sir J. Thwaites.*) They are not overshot mills, I suppose ?—No, they are undershot mills.

3703. (*Col. Harness.*) Do you remember how many pairs of stones they work ?—I am not quite sure about that, I think it is five pairs of stones.

3704. (*Sir J. Thwaites.*) Have you observed any other spring in the neighbourhood ?—No ; this spring at Havant (*pointing to the sketch*) is what I have termed the waterworks spring for the supply of the town of Havant, which I have not included in this estimate.

3705. Then the supply of the town of Havant is exclusively taken from the town spring ?—The waterworks are built over a spring which, after supplying the district, leaves a surplus which forms the Brookhampton stream, and at 500 yards from its point of issue discharges 13,450,000 gallons every 24 hours into the sea. This spring is not included in what I call the town springs.

3706. Have you gauged the flow from the Havant town springs ?—Yes, it is 9,000,000 gallons every 24 hours.

3707. How often have you gauged it ?—Some scores of times.

3708. Do you find any variation ?—Except in the long drought of 1864, it has been so little as to be almost imperceptible at any time of the year.

3709. Now as to the Langbourne springs, of which there are three, what is the quantity obtained from those springs ?—9,000,000 gallons every 24 hours. Then there are two springs at Warblington which yield 4,500,000 gallons, and the Westbourne springs flowing through Emsworth yield 13,500,000 gallons.

3710. What is the distance between those several springs ?—It is two miles from Emsworth to Bedhampton.

3711. You have taken the volume of water in all those springs, except that which supplies the waterworks for the town of Havant ?—I have ; I have excluded the supply requisite for the district.

3712. What is the available quantity from all those springs ?—134,850,000 gallons.

3713. With the exception of taking the water from those mills, there is no other evil is there that would arise from the abstraction of the water ?—No; it only supplies the mills named, and then flows into the sea. All the springs could be tapped and brought to a point at Bedhampton, where a reservoir could be constructed.

3714. How far is the point of Bedhampton from the metropolis ?—64 miles as the crow flies.

3715. Have you formed any estimate of the cost of bringing that water to London ?—Yes, I have made inquiries upon that point.

3716. Not being an engineer, have you taken the opinion of any person who is competent to form a sound judgment upon the matter ?—Yes, I think so. To purchase the whole of the mills which possess water rights would require 50,000*l.*, and the subsequent value of those mills, that is to say with the water abstracted, supposing they were turned into steam mills, would be 40,000*l.*, leaving the cost of obtaining the whole water rights at 10,000*l.*, and my total estimate for the whole of the works until the water is delivered into the mains of the existing water companies in the metropolis is 1,280,000*l.*

3717. Whose estimate is that ?—Mr. Butter's, of Hackney, a large builder and contractor, and a man of great business capacity in matters of this kind.

3718. Then the deprivation of water rights you estimate at what ?—10,000*l.* ; and the cutting of a trench for two miles to tap all the springs, 20,000*l.* Of course the water will have to be raised to a certain level.

3719. What is the level of the point at Bedhampton ?—15 feet above Trinity high water in London.

3720. What fall do you give ?—I propose to pump the water into a reservoir at about the height of 180 feet.

3721. That would be a fall of 195 feet ?—Yes.

3722. (*Col. Harness.*) What is the distance of the reservoir from the place where you pump ?—I should say about a quarter of a mile.

3723. (*Sir J. Thwaites.*) Do you get a fall of 180 feet in a quarter of a mile ?—The proposed reservoir, a vast chalk quarry, is situated at the top of the eastern spur of the Portsdown hill, upon which the new line of forts are constructed, and at this point possesses an incline of about 40 degrees. This quarry, with little alteration, would contain 20,000,000 gallons.

3724. What is the cost of your culvert ?—My estimate for the works and machinery requisite for pumping so large a body of water into the receiving reservoir just named is 120,000*l.* ; the water could then be conducted in an open cutting 25 miles to the large fountain reservoirs situated amongst the chalk hills laying south and south-west of Petersfield, or to the immense sandy waste known as Woolmer Forest, which, at a cost of 10,000*l.* per mile, would be 250,000*l.*, and from the fountain reservoirs to Weybridge, a distance of 25 miles, in a substantial cemented conduit.

3725. What is the size of your tunnel ?—It would be 12 feet in diameter, at 15,000*l.* per mile, for 25 miles, costing 375,000*l.*

3726. What will you have to cut through there ?—Only chalk and sand.

3727. If you get into the sand you will have to concrete, will you not ?—Undoubtedly. I propose to make the principal reservoir between Petersfield and Liphook. There is a succession of chalk hills from Havant to that point.

3728. Are we to understand that from this reservoir at what you call your pumping station a quarter of a mile from Bedhampton, the water will flow by gravitation to the reservoir between Petersfield and Liphook ?—Yes. It is a matter of small importance as to the precise spot at which the fountain reservoirs are formed, because there are so many facilities for forming such reservoirs that the water may be stored to almost any extent in the said district.

3729. What height are you at your reservoir at Liphook above high water?—The volume of water discharged by the before-mentioned springs will form a stream 30 feet wide, 3 feet deep, with a flow of two miles per hour, and to give that velocity would require a fall of 18 inches per mile, and would leave an

G. W. Ewens, Esq.

23 May 1867.

elevation at the surface of the fountain reservoirs at Petersfield of about 160 feet.

3730. Starting from that point towards the metropolis, what line do you take?—After passing the Liphook station I should bring it past Godalming and Guildford to Weybridge, and then cross the Thames with one portion of it. I should divide the stream at Weybridge, and bring a sufficient quantity to Thames Ditton to supply the southern districts of London, and I should take a larger supply round to the north to Lea Bridge for the East London Company, the New River Company, the Chelsea Company, and other companies.

3731. How do you propose to supply the higher parts of the metropolis?—I think you will find that the elevation of the fountain reservoirs will be quite sufficient to discharge the water into the works of all the existing water companies in any part of the metropolis.

3732. You are, as I understand, 160 feet high at the reservoir, and you will consume part of that by your gravitating power up to the metropolis?—The weight of the water will carry it to the metropolis with only a loss of about one-third of elevation.

3733. When you arrive in London what height are you above high water?—If you take as a test the Croton aqueduct, near New York, you will find the fountain reservoir possesses an elevation of 166 feet above that city, at a distance of 38 miles from the distributing reservoir on the island, and requires a fall of 15 inches to the mile to give the water a momentum of $1\frac{1}{2}$ miles per hour, thus reducing the elevation of the water near the city to 119 feet, so that, allowing for greater speed and to carry the water into all the water companies works, we should still have a pressure equal to 50 feet of elevation.

3734. But when you arrive in London at Lea Bridge, is that your general reservoir?—No, that would be for the supply of the East London Company only.

3735. How do you propose to supply the western parts of the metropolis?—I propose to supply the west of London by the various existing companies.

3736. Your plan shows a line to the East London Waterworks station, and that you say is for the supply of the eastern district; how do you propose to supply the western part of the metropolis; where would your reservoir be for that supply?—I do not know that to deliver the water into the pumping works of the existing water companies would require another reservoir, but if it should be so, a distributing reservoir for the western districts could be formed at Wormholt Scrubs, and thence distributed to the Chelsea, Grand Junction, West Middlesex, New River, and East London Companies, and supplied by them through the existing system.

3737. You would not carry it down to the east and then carry it back again to the west?—Certainly not. Starting from the division of the conduit at Weybridge, the supply necessary for the whole of the Middlesex side of the river I should carry as near as possible to the works of the existing companies and deliver into their works up to the extreme point of requirement, that of the East London Company at Lea Bridge.

3738. You have not indicated any line?—I thought it scarcely necessary to do so.

3739. When you have arrived at Lea Bridge, in order to bring the water towards the western part of the metropolis, you will have to pump it again, will you not?—The water carried to Lea Bridge will only be that required for the supply of the eastern district, and at this point there will be a sufficient pressure without pumping to carry the water over the whole of the East London district.

3740. Of course your channel is not under pressure, because you have an open cutting?—The only portion of the distance the water will be conveyed in an open cutting will be before reaching the fountain reservoirs at Petersfield, as the water will be conveyed by a substantial conduit from that point, and as that conduit would be at such an elevation that from the surface of the lakes to the level at which the water would cease to flow through the conduit would of course give a pressure of many thousands of millions of gallons, because a depth of 100 feet might be given to these lakes if necessary.

3741. Then the channel is not under pressure?—Not before reaching the fountain reservoirs, but afterwards, yes.

3742. Do you mean to say that you will have 180 feet of pressure at the point where you describe this reservoir to be situated in Woolmer Forest?—No, 160 feet.

3743. And will you go in a covered tunnel all the way from that point to the metropolis?—Yes, all the way.

3744. By iron pipes?—Either by iron tubes or strongly constructed conduit.

3745. And you put those pipes under the pressure due from 180 feet of elevation, is that so?—There would be of course some means of regulating the flow of the water through that conduit.

3746. You have probably not directed your attention to that point?—My view of the matter was, that the existing companies should be allowed to take this supply of water, and to distribute it according to their present arrangements, so as not to interfere with their already vested interests.

3747. (*Col. Harness.*) You idea is to carry the water by a proper aqueduct past the works of all the London Water Companies up to the most eastern district, and as you pass to give it to those companies?—Yes, decidedly. At Thames Ditton I propose to give them a sufficient quantity for the southern district and let them pay for it, and then to bring the remaining portion across the Thames to supply the northern district.

3748. And you would deliver it to them from the altitude that the water in your aqueduct would have at the point at which they take it?—Yes.

3749. And it will be for them to utilize it?—Yes.

3750. (*Sir J. Thwaites.*) What is the entire cost of your scheme, including the reservoirs?—1,280,000*l.*, and that is a sum which those companies could raise amongst themselves. The whole scheme will not require more than half the amount required for the recently constructed works at Glasgow.

3751. Have you had any analysis made of the water?—The water is simply pure. This is Dr. Hassall's analysis of the water (*producing the same*).

3752. When was that made?—On the 19th of October 1866.

3753. Will you put that table in?—Yes. (*The witness delivered in the following table*):

RESULTS of the ANALYSIS of a SAMPLE of WATER received from MR. EWENS, October 12th, 1866:—

Constituents of an Imperial Gallon.

	Grains.
Carbonate of lime	13·82
Carbonate of magnesia	1·03
Sulphate of lime	·42
Sulphate of potash	·67
Sulphate of soda	·35
Chloride of sodium	2·00
Silica	·68
Alumina and iron	·44
Nitric acid and ammonia	none
	19·41
Matter destroyed by heat, partly organic matter	1·04
Total solids	20·45

The oxidizable organic matter in this water is but small, and much less than is contained in the water with which London is now supplied. On the whole this water may be said to be a pure and wholesome water.

ARTHUR HILL HASSALL, M.D.,
Author of "The Microscopical Examination of the Water supplied to London;" of "Food and its Adulterations."

3754. (*Mr. Harrison.*) What is the degree of hardness of the water?—In its present state about 14

degrees of hardness. But if the Watford water, the component parts of which nearly approaches this water (except its organic matter) can be reduced by Clark's process from 17·45 degrees to 2·74, so this water, containing a smaller amount of lime salts, could be raised to a higher standard than that of Watford.

3755. (*Mr. Prestwich.*) This is very similar to the New River ordinary chalk water, is it not?—In point of inorganic matter it is.

3756. It contains carbonate of lime nearly 14 grains. What degree of hardness did you say it was by Clark's test?—In its present state about 14 degrees, but by Clark's softening process it could be reduced to less than seven degrees.

3757. Is it not more than that?—Not as compared with the Watford water.

3758. You have not come to that conclusion by the test?—No; Dr. Hassall did not give me that. I only arrived at that by comparison with other waters.

3759. Do those springs rise in the chalk?—The water is no doubt thrown up from fissures in the chalk, although the valley is composed of a stratum of heavy solid clay many feet in thickness.

3760. But the clay in the neighbourhood of Havant is London clay, which overlies the chalk; you do not come to clay at the base of the chalk?—I had an idea from its purity, gravity, and colour that it more nearly approached the Poole clay, and that this valley was an extension of the same basin; however that may be, we should find this clay, which extends more or less from Bishop's Waltham to Littlehampton, over the whole of Hayling and Thorney islands, and inland to Haslemere, exceedingly useful for making bricks for the works.

3761. At all events it would be the tertiary clay overlying the chalk. Have you any well in that district which traverses the chalk and reaches the clay beneath it?—Yes; I had a pump at Warblington, where I lived, and this well went through a thin layer of gravel and chalk, and then down to this bed of clay upon which the water rested.

3762. You would not have a thin bed of chalk under those circumstances; the chalk in that district is exceedingly thick, is it not?—Undoubtedly chalk forms the base of the district. The thin stratum mentioned very closely resembled chalk, and was used as a substitute for it to mix with clay in the manufacture of bricks.

3763. I think you are wrong, because the chalk dips again beneath the tertiaries and between there and the sea; it is merely a ridge of chalk?—It may be so. On that particular spot I know I am right, but it may not be so as a rule.

3764. I believe you will find that the chalk there is several hundred feet thick; however, that would be immaterial to your argument. You state that there are springs here of a certain volume which issue probably from fissures in the chalk, whatever may be the position of the clay with regard to the chalk?—Exactly so.

3765. The first of those springs you have gauged at 87,000,000 gallons?—Yes, the first set of springs at Bedhampton.

3766. And those gaugings you have conducted at infervals of several weeks?—Yes, for five years.

3767. How have you made the gaugings?—I have made inquiries of the millers as to the weight of water required to drive their mills, and the number of hours they can drive their mills from those springs; that is one way. Then where the water has been confined within a channel, I have measured the width, and depth, and velocity with which that water is constantly flowing when the mills are not at work; that is to say, the waste water, and from those calculations I think I am considerably under the mark. I have allowed a margin for contingencies, but I imagine that the water amounts to really, in fact, 150,000,000 gallons per day. I have therefore left a margin of 16,000,000 in case of an error. I may here say that should not this quantity be sufficient, although nearly double the present supply, another 50,000,000 can be added by absorbing two streams near Petersfield, and over or near which the conduit would have to be carried. The water is equally pure, and would bring the total to 200,000,000. There are also means of very considerably increasing even this quantity.

3768. Is no use made of those springs except for the supply of the mills and the town of Havant?—None whatever.

3769. They are not used for any water supply?—Only for the supply of Havant from the existing waterworks.

3770. The channel by which you would carry the water from the neighbourhood of Havant to London passes first through the chalk ridge of the South Downs?—Yes; it would be raised to a very large reservoir, which has been excavated for a great number of years, at the side of the hills on the eastern spur of Portsdown hill, at Bedhampton.

3771. Should you not have to carry it through the Downs the greatest part of the way through a tunnel?—I think it might with perhaps a little tunnelling be carried by means of an open cutting the greater portion of the distance from this first reservoir to the lakes or fountain reservoirs I should propose to form near Petersfield, in the neighbourhood of which the water could be stored to any extent.

3772. You pump it to a height of about 190 feet, but that height would not be sufficient to carry it over the South Downs without tunnelling?—Perhaps not entirely without; as near as I could judge, about three miles of tunnelling through the chalk, allowing a gradient of about 18 inches per mile, or a velocity of two miles per hour, to the water.

3773. And from Petersfield to Guildford you traverse a district which for the main part consists of sand?—Yes.

3774. But there are sands through which you will have to carry the water either by pipes or by a channel, which would have to be cemented?—Precisely so; as far as Weybridge, I apprehend.

3775. When you cross the Thames at Weybridge, at what height should you cross it?—At Weybridge, where it is proposed to divide the supply, we should have an elevation of about 130 feet; and I think if the water were conveyed from the junction to the Thames, a distance of about two miles, by means of iron tubes, the level might be so depressed as to allow the aqueduct over the river to be constructed at, say 30 or 40 feet.

3776. Your object would be merely to deliver it to the reservoirs of the companies in London at their present level?—The water companies seem to be entirely at a loss to find a pure supply of water at such a cost as to enable them to obtain it, and my object is to direct the attention of the Commission to this supply, and by such measures as may be deemed advisable to enable the existing water companies to raise amongst themselves the capital required to convey this water into their several reservoirs, and from thence supplied to the metropolis by the existing service system; by this means the invested interests in the water companies, amounting to many millions sterling, will be protected, good dividends will still be paid without increasing the present water rates, which must be a necessary consequence on the adoption of any more expensive scheme.

3777. Then you would have a very great fall from Woolmer Forest to London?—Yes, a fall of about 160 feet; and provided the fall was economised by having a sufficiently strong conduit to bear the pressure, we could carry it into the highest reservoir in London.

3778. (*Mr. Harrison.*) Your scheme involves pumping at Havant?—Yes.

3779. And you would deliver it to the water companies at a level from which they would have to pump it again?—Yes, except in the case of the Lambeth, Vauxhall, and East London Companies, who would have sufficient pressure to carry it over their several services.

3780. But you propose to make your reservoir at

G. W. Ewens, Esq.

23 May 1867.

Woolmer Forest 160 feet above ordnance datum?—Yes.

3781. What fall would you calculate per mile from that to London?—18 inches per mile would give the water a velocity of two miles per hour.

3782. For how many miles from Woolmer Forest to London?—Supposing the reservoir to be at Woolmer Forest, which is just below Liss, it would be 38 miles to Charing Cross.

3783. Taking it at 40 miles, and says 18 inches fall per mile, that would reduce your head of water in London to 100 feet above ordnance datum?—About 100 feet.

3784. Are you aware that there are a great many houses in London which are 200 feet above ordnance datum?—I imagine there are some houses which are over 200 feet above ordnance datum, but my object was not to bring a sufficient pressure upon this water to carry it to that altitude, but to leave it to the present companies to make use of their present machinery.

3785. In point of fact your scheme involve, first, lifting the water by pumping at Havant, and a second lifting by the water companies in London?—Yes, except in the case of the three companies named.

3786. Can you get over the country without raising it?—Yes, we could get over it by a syphon from Havant, and deliver it to the present water companies without any artificial lifting between that point and London.

3787. What is the level of your springs at Havant?—15 feet above Trinity high water.

3788. I think you must be mistaken in supposing that you could deliver it by a syphon?—Not from that point. I am speaking now of taking it from the reservoir at Bedhampton on the Down hills.

3789. You must have one pumping at Havant to get to the reservoirs, and when the water gets to London you require another pumping?—Just so.

3790. Do you imagine that the water of those springs does not come from the chalk?—The watershed embraces at least 50 square miles, for the most part consisting of chalk and sandy surfaces, through which it percolates until finding an outlet in the valley.

3791. What is there to make this water different from ordinary chalk water?—It is not essentially different, the only difference is that it contains no organic matters. Its component parts are similar to the Watford water, with the exception that it contains no organic matter or acids of any description.

3792–3. (*Mr. Prestwich.*) You say that it contains no organic matter, the analysis does not bear that out, does it? The matter destroyed by heat, partly organic matter, is 1·04; that would indicate a certain quantity of organic matter, would it not?—I imagined from what Dr. Hassall's assistant told me, that it was comparatively free from organic matter. I imagine that the water which was taken for this test was perhaps hardly a fair sample, it was taken from one of the streams running from the springs. The streams running from the springs would naturally contain animal life of some kind or other, and I fancy a small amount of organic matter may have been found in the stream which would not have been found in the water at the spring head.

3794. It is not a large amount at all events?—No. The principal objection to the water, of course, is the lime which it contains, but there is no more lime in it than there is in all waters supplied by the chalk, and it could be reduced by Clark's process to two degrees of hardness. I might say that my total estimate includes 25 miles of cemented aqueduct reaching from Weybridge to Lee Bridge.

3795. Those springs I presume are well known in the district?—Yes, very well known.

3796. Has it been ever considered to use them for the supply of Portsmouth or any of the adjacent towns?—I have considered it, and intend, provided the supply is not thought sufficient for the metropolis, to endeavour to obtain powers to carry it coastwise to supply Portsmouth, Gosport, Chichester, Littlehampton, Worthing, Brighton, Eastbourne, and Hastings, which towns are very badly supplied with water.

The witness withdrew.

Adjourned to Wednesday next at 11 o'clock.

Wednesday, 29th May 1867.

SIR JOHN THWAITES IN THE CHAIR.

Alderman SIR BENJAMIN PHILLIPS.	THOMAS ELLIOT HARRISON, Esq.
Colonel HARNESS.	JOSEPH PRESTWICH, Esq.

A. Bain, Esq.

29 May 1867.

ALEXANDER BAIN, Esq., examined.

3797. (*Chairman.*) What position do you hold?—I am Professor of Logic in the University of Aberdeen.

3798. We understand from a letter which you have addressed to his grace the Duke of Richmond that you have given considerable attention to the question of water supply?—Yes, owing to my having been assistant secretary to the Metropolitan Sanitary Commission and then to the General Board of Health, and having also been on an intimate footing with a number of scientific gentlemen who have investigated this question, I may say that my knowledge is pretty intimate as to the course of inquiry for a certain number of years. It was on those grounds that I chose to intrude myself on the Duke of Richmond, and not as being entitled to speak before the public with authority as to the conflicting schemes.

3799. Your letter points to two sources of supply, one of which is the Watford chalk?—Yes.

3800. Upon which a considerable amount of discussion took place in the years 1850 and 1852?—Yes.

3801. And it also points to the Bagshot sands?—Yes, I am well acquainted with the course of official inquiry on both proposals.

3802. You refer to the purity of the water from those two sources. Have you paid any attention as to the volume of water which could be obtained?—Of course I was perfectly aware of the nature of the evidence that was presented to the Board of Health. The Board chiefly took up the Bagshot scheme. It was I may say their scheme. I know what their evidence was, and I also know what the evidence has been with regard to the Watford supply; at least I know the documents and authorities that gave that evidence.

3803. That was in 1850, I believe?—Yes, the Inquiry and Report of the Board of Health was in 1850.

3804. Can you give the Commission any information as to the quantity of water obtainable from the Watford source?—Of course I am not prepared with the exact documentary evidence that I could furnish if I were to be asked to do so; in fact I did not know exactly what things the Commission would ask me, therefore I am not prepared with any specific documentary evidence. I can tell, by referring to the Report of the Chemical Commissioners, what opinions were formed on the subject at the date of that Report.

3805. You are probably aware that the quantity of

water is a question of great importance in this inquiry? —I am aware of that, but I was not aware that the Commission would expect me to give any information upon that point. I should require a few days to refer to the evidence or to find out the parties. Of course there are parties much better able than I am to give that evidence.

3806. You speak in your letter of certain inquiries having taken place and certain reports being presented to government and to parliament, and you are surprised that the public have not paid more attention to these reports?—Yes, certainly.

3807. And surprised that this inquiry should now be instituted in the presence of those reports?—Yes, that is quite the case.

3808. One would naturally suppose, therefore, that you had paid attention not only to the quantity of the water which it is ascertained could be obtained from those two sources of supply, but also the quality?—Of course I have paid attention to the evidence given by gentlemen who are entitled to speak upon that point. I have before me the report of the Government Commission of 1851.

3809. Can you tell us from the evidence of those gentlemen as to the quantity of water obtainable from the Watford scheme first?—I can refer to the report of the Chemical Commissioners appointed by Sir George Grey in 1851, who were Mr. Graham (now the master of the Mint), Professor of Chemistry in University College, Dr. Miller of King's College, and Dr. Hofmann. Those were the Commissioners, and if the Commission choose I will read the questions that were put to them.

3810. Were any other than chemical questions referred to them?—Yes, the question of quantity was referred to them as to both sources; they had referred to them the question of the present supply, the Bagshot supply, and the Watford supply, and the evidence as to the quantity. The report is signed by Mr. Graham, Dr. Miller, and Dr. Hofmann, Sir George Grey's letter being dated the 23rd of January. The passage in which they speak of the quantity is this short sentence. They say, "The proposals of the "London (Watford) Spring Water Company" (whose water was referred to them) "extend only to a daily "supply of about 8,000,000 gallons." That was the proposal of that company. "But the area of land "sloping towards Watford, and consisting, for the "most part of chalk hills, embraces more than 1,200 "square miles, and is estimated by Mr. Homersham, "the engineer of the company, as equal to a daily "supply of 408,000,000 gallons, the quantity of "water which reaches the lower fissures of the chalk "being calculated at one half of the rainfall." That is the calculation, and they go on to give another fact, quoting Mr. Stephenson's original report of 1840. "A well sunk in Bushey meadows in 1840, "when this source of supply was first recommended "by Mr. Robert Stephenson, has been found capable "of yielding, by pumping, 1,800,000, or nearly "2,000,000 gallons per day;" and then they give the particulars of the well. That was from one well, which was used as an experiment of what could be got. The detail is given of the construction of the well. "This well is 12 feet 6 inches in diameter at "the bottom, and 34 feet deep, with four small bore "holes, 5 inches in diameter, descending 130 feet "below the surface of the ground."

3811. Are you aware whether that district has been additionally taxed since then, or whether it is equal to the yield referred to by the Commission?—No, I cannot undertake to give evidence upon that point; indeed, I am merely repeating the evidence that was given in 1851.

3812. And now, as to the question of the purity of the Watford water, what was the opinion of the Commissioners?—Upon that point the Commissioners speak very decidedly, because they speak from their own personal investigation, and this is their statement of the general character of the supply:—"First, the "spring water contains no matter in suspension to "cause turbidity or colour; its clearness and brilliancy "are unexceptional. 2. It possesses a desirable cool- "ness, having at all seasons a temperature between "50 and 52 degrees. 3. The amount of organic "matter it contains is inconsiderable, and of a kind "which appears to be incapable of undergoing putre- "factive decomposition, so that it may be safely dis- "regarded. 4. The salts which it contains would not "interfere with its use as a beverage. It is, indeed, "a choice water for drinking. 5. The great and "obvious objection to the chalk spring water is its "hardness, which, when the water is first drawn, is "uniformly very nearly 18 degrees, or 4 degrees "harder than the present metropolitan supply. "The weight to be assigned to this objection, how- "ever, appears to be much reduced by the following "considerations," and then, with regard to this, they go with some minuteness into the process invented by Professor Clark, of Aberdeen, for softening or reducing the hardness, a process which they completely investigated, and on which they pronounce a very decided opinion in another part of the report. In conclusion, they say that "the chalk spring water, after being "softened, is an extremely pure water. It appears "to be considerably superior even to the soft water "from the stream of the Surrey sands."

3813. Do they get rid entirely of the hardness?—Not entirely. They reduce it to two or three degrees, but it then stands comparison with the very softest waters of the country. "It appears to be considerably "superior even to the soft water from the streams "of the Surrey sands. The chalk water alone is "uniform in its excellence at all times, the sources "of it lying beyond the influence of weather or "season. In the judgment of the Commissioners "this softened chalk water is entitled, from its "chemical quality," (that is a point on which their authority is pre-eminently high) "to a preference over all others for the future supply of the metropolis."

3814. (*Sir B. Phillips.*) Is there any reference made there as to the cost of that softening process?—No, I think not; but, of course, as the process is in operation, it would be very easy for the Commission to get that information from the parties who have put the process in operation.

3815. (*Chairman.*) Is that degree of hardness, 18 degrees, the mean, or is it the maximum?—It is a steady water; it is the nature of spring water to have great steadiness.

3816. (*Mr. Harrison.*) Have you had any experience yourself of Professor Clark's process upon a large scale?—I have seen it in operation.

3817. At Watford?—No, it never was introduced into Watford; the Watford Company never was carried out.

3818. Where have you seen it in operation?—I saw it at Plumstead, near Woolwich, where it was in operation for a number of years.

3819. (*Chairman.*) Were those Davis' waterworks? —I suppose so. However, those waterworks have since been bought up by the Kent Company, and they use the chalk-water, but without softening. The process has been introduced into various other places. It has been in operation for a number of years at Caterham; and Caterham water represents a fair average example of the chalk-water.

3820. Do the Commissioners refer to the rainfall on the Watford district?—They make a reference to the rainfall.

3821. You state, did you not, that the quantity referred to was one half the rainfall?—Yes, that is the basis of the calculation.

3822. That one half the rainfall finds its way to this chalk basin?—Yes, it is supposed to do so.

3823. (*Mr. Harrison.*) You do not give any chemical opinion, do you, of your own knowledge?—I am not a chemist. I have gone through a considerable range of scientific studies, and I believe that I have some capability of estimating scientific evidence, but I am not a practical chemist, and never was. Of course the Commission can refer to Mr. Graham or any of those chemical gentlemen upon those points.

A. Bain, Esq.

29 May 1867.

3824. (*Chairman.*) Can you give the Commission any evidence of the Bagshot water, first as to the quantity, and secondly as to its quality?—Of course if I had an opportunity of referring to the report of the Board of Health I could very easily give you the exact points, but I now merely speak from memory.

3825. Did those three professors examine the water of Bagshot?—Yes, they did. Their results are in the Report before me. They first give the examination of the springs from the Bagshot sands, taking six selected springs, of which they give a very detailed analysis. The detailed analysis is cumbrous, but they give also a separate statement of the degrees of hardness. The six springs taken together represent an average hardness of 2·18 degrees. They remark that "those springs therefore exhibit an average "hardness of a little more than 2 degrees" which undoubtedly is very soft water; it is one of the softest waters that can be had. And then they state "the "value of this extreme purity and softness is not di- "minished by the other mineral and organic consti- "tuents of the waters which are insignificant in "quantity, and really of no account." They farther remark that "the nearly entire absence of carbonic "acid from these waters to which attention has been "drawn by Mr. Napier, is perhaps their most singular "chemical feature," so that they have a very decided opinion as to the quality of this water, and anybody who has been in the neighbourhood would say the same thing. I have myself known some of those springs; I happen to have lived at Moor Park; and in the grounds of Moor Park there is a well or a stream issuing from a cave called Ludlam's cave, the water of which was examined carefully by Professor Clark, who is the great authority on water. He pronounced it the softest water that he had ever examined: so that in fact the quality of these waters, or at least of these springs, is of a very high order. Then the Commissioners go on to speak of the quantity. "The question, however, arises how "far these springs represent the large supply of "upwards of 20,000,000 gallons which it is proposed "to draw from this district." Speaking from recollection, I understand them to refer to the quantity named in the report of the Board of Health, who alleged in their report, that they could procure 20,000,000 gallons of that exceedingly fine water. Of course the Commissioners visited the district and made a personal inspection to verify the statement which the Board of Health made upon the inspection of their officer, and they say in their report, "The visible springs are not very numerous, "nor did the yield of each appear very great. The "water from the largest might be carried off by a "two-inch pipe. It is proposed," (quoting from the Board of Health) "'to lead away the deep springs "only' extending 'the shallow land springs and "surface drainage.' The possibility, however, of "keeping these different waters separate appeared "to us extremely doubtful. The high ground consists "entirely of beds of siliceous sand, rarely indurated to "any extent or converted into sandstone which "constitutes enormous storing reservoirs for the "springs." I understand them to say that they are not indurated into sandstone so as to be retentive. "The springs are at all levels and a partial outfall of "water may take place at any point on the declivities, "and is not determined to a certain line, either hori- "zontal or vertical by the occurrence of a retentive "stratum, such as a bed of clay or rock along the "outcrop of which spring water might be collected," (that seems to be with regard to the difficulties of gathering it), "hence the slightest cause may occasion "the loss of a spring and its reappearance at another "point of lower level—from few or more of these "springs can the flow be accurately gauged, and it "was not attempted by the Board's engineer, Mr. "Rammell, to the gauging of the small streams or "rivulets even. Mr. Rammell observes, 'an insuper- "able obstacle,' was found 'in the porous nature of "the beds of these streams which rendered all "attempts to intercept or divert the whole of the "flow hopeless. From this cause it was quite im- "practicable either to draw up the water effectually "or to lead it along an artificial channel laid at a less "inclination for discharge into the box (in which the "water was to be measured); most of the smaller "streams have beds of perfectly clean gravel through "which, on the current being arrested, escape imme- "diately takes place. It appeared, indeed, on close "examination, that even the ordinary run of these "streams is not wholly over or above the surface, but "partly within the bed of the channel itself, much of "the water thus passing away insensibly between the "pebbles. Any attempt to dam up these streams "with a view to gauging over a weir must have "failed from the same cause." Those remarks are to show that they consider the quantity of the supply a matter of entire uncertainty.

3826. The calculation is that it would yield 20,000,000 gallons per diem?—The Board of Health calculated that.

3827. But that is not certain?—No.

3828. No reliable gauging was made?—No, and the difficulties of collecting are also alluded to.

3829. (*Mr. Harrison.*) Living as you do in Aberdeen, you have of course had an opportunity of putting some value upon the soft water which you there use?—Yes, no doubt.

3830. If my recollection serves me rightly, your water is about as soft as any in the kingdom?—I think it is about as soft as any.

3831. (*Chairman.*) It is the granite water, is it not?—Yes. It is the water from the granite high up the country.

3832. (*Mr. Harrison.*) Should you consider that if chalk water were supplied to London it would be necessary to soften it by Clark's process?—That water, I apprehend, has very decided merits independently of Clark's process, and of course those merits can be judged of from the very great range of towns that are now supplied with it; but then there is no doubt that this addition, as the Commissioners say, takes away the one great cause of objection; and with that, I think, the Commission may safely say (at all events it is the opinion of those chemical Commissioners) that the water is equal to any supply in any place.

3833. With your experience, if you had the option of supplying a town with that chalk water, or with such water as Aberdeen is supplied with, to which should you give the preference?—I would not undertake to give a preference without a full investigation of the two cases; but I apprehend that the chalk supply is really perfect, that is to say, no objection can be urged against it. I do not mean to say that a water might not be found one degree softer or two degrees softer.

3834. You have referred to Moor Park, are you aware that that is the residence of Mr. Bateman, the eminent engineer?—Yes, I understand that it is so. I was there long before he purchased it; I have merely a recollection of that well, which is a very remarkable one.

3835. Perhaps you may not be aware that since Mr. Bateman has resided there he has been to the expense of bringing that soft water, to which you have referred, to his own house?—I believe that Dr. Clark advised a former occupant of the house to do the same thing.

3836. Could you offer to the Commission any decided opinion as to the real value of such water as you have at Aberdeen over hard water?—Of course it is now well understood what the precise advantages of softness are; these have been recognized and admitted ever since that discussion began. First and foremost, with regard to washing, the economy is very great in soap and in labour. Then there has been, at various times, a good deal of testimony given as to the culinary value of soft water; for example, as to tea, there can be no question at all as to the great superiority of soft water. It has also been said to possess advan-

tages in respect to other culinary preparations; but the evidence is somewhat conflicting, and, therefore, I would not put stress upon any other points, as far as my own knowledge goes, except washing and tea. The washing interest is a very large interest, and in the first evidence given with regard to the softening process, which was Dr. Clark's own evidence before the Health of Towns Commission, he gave a computation of what he considered the saving of soap from the use of soft water.

3837. I gather from your view of it that you would prefer chalk water, you having the means of making it soft if you wished it?—So far as my knowledge has gone, that seems to me to be a perfectly satisfactory supply. I do not mean to say that a full comparison might not show advantages in another supply.

3838. In your letter you state the fact that injurious effects have been discovered from the supply of water to Glasgow from Lock Katrine?—I did not exactly intend that, but what I meant to say was, that there were certain scientific men who expressed misgivings or doubts about the perfect purity of the water in point of organic matter. That is a point so exceedingly subtle that it is the hardest thing possible to get very decided evidence upon it when it is not a broad apparent fact. One thing is certain, that you must combine with the chemical examination, a microscopic examination in the hot months.

3839. You do not give that as a matter based upon any actual experience, but merely as a matter of opinion?—I merely say that such opinions have been entertained by scientific persons; you are aware that those measures are all canvassed by opposing parties.

3840. (*Mr. Prestwich.*) There is a new supply to Aberdeen is there not?—Yes, there is a supply taken higher up the Dee.

3841. And that water is perfectly soft?—It is the same as the former with regard to softness, and it has the advantage of greater purity as regards mud or sediment.

3842. Have you ever heard of any objections raised to the use of soft water there?—Never; probably you allude to the question of the action of the water on lead.

3843. Or from its taking up organic matter with greater facility than hard water, or from any cause whatever?—No, I am not aware of any complaints. The question of the action on lead has been a matter of chemical investigation, and the results of that can be obtained if necessary.

3844. As far as regards that, it is a perfectly satisfactory supply?—Yes.

3845. (*Chairman.*) Is it an intermittent supply or a constant supply?—It is a constant supply.

3846. How long has that constant supply been in operation?—The date of the supply which has just been superseded is about 1830, to the best of my recollection. That was upon the principle of constant supply, and the new supply continues the same.

3847. Therefore it has been 37 years in operation?—It must have been that time.

3848. To your knowledge has any inconvenience arisen from the constant supply?—I am not aware of any.

3849. Have there been any complaints as to the waste by the consumers?—Last year, just before the new supply had come in, and when the town was dependent upon the old supply, which had become insufficient, there was a great scarcity of water; and at that time people indulged in comments upon the inhabitants in some of the lower districts carelessly allowing the taps to run; but until the town generally began to feel the scarcity, they made no remarks about it. The present supply is above all possibility of shortness.

3850. Do you know the system of supply to the poor, have they any cisterns, or simply a tap?—I rather think that in the poorer class of houses there are no cisterns.

3851. Are there standcocks?—Yes, there are standcocks in the streets.

3852. (*Mr. Prestwich.*) What is the supply per head at Aberdeen?—I am not sure that I can give the estimate offhand upon that point.

3853. There have been several reports, have there not, published upon the supply from the chalk from the Watford wells?—I am aware that there have been reports subsequent to the report of the Chemical Commissioners.

3854. The experiments at Watford were conducted for some considerable time, were they not? I mean the pumping apparatus?—The experiments of Mr. Stephenson are given in his report of 1841, which I have now before me, but I understand that the reasoning as to the Watford supply depends upon the computation of a good many different wells that are used for local purposes.

3855. Are you aware of the effect which that pumping and those experiments at the well produced upon the flow of the river?—I cannot answer that question.

3856. Do you know the maximum quantity that was pumped?—No, I cannot undertake to give the Commission the precise quantity.

3857. Nor are you probably aware of the gauging of the river Colne at the lower part of its course after it receives all the chalk springs of that district?—No.

3858. You state, do you not, that the hardness of the water could be reduced by Clark's process to two degrees?—I should not have mentioned the precise figure because that is somewhat a variable limit. In the most favourable waters it comes down to from two to three degrees, but it has not been brought as low as that in all cases. I would again respectfully state to the committee, that I do not consider myself as an authority upon this question. I speak merely from official and other means of being acquainted with the previous inquiries, and as in some degree competent to bring before you the facts which other men have given. I cannot undertake any personal responsibility in advising the Commission.

The witness withdrew.

WATERWORKS constructed under the direction of Mr. S. C. HOMERSHAM, Civil Engineer, to supply SPRING WATER softened by Dr. CLARK'S process.—June 7th, 1867.

Name of the Works.	Date when Works were opened.	Hardness of the Spring Water.	Hardness of the Spring Water softened.	Solid Contents of the Spring Water.	Solid Contents of the Spring Water softened.	Source of Supply.	Observations.
		Degrees.	Degrees.	Grs. per Gal.	Grs. per Gal.		
Plumstead, Woolwich, and Charlton Consumers Pure Water Company.	Augt. 1854	21	7½	31	18¼	Spring water from the chalk formation	These works were specially examined by order of the Government and favourably reported upon in 1856 by the late Henry Austin, Esq., C.E., Chief Superintending Inspector of the General Board of Health, and the report printed by order of Parliament. The works were purchased from the original company in 1861 by the Kent Water Company. When the works passed into the hands of the Kent Company, to the great annoyance of the consumers, the Kent Company ceased to soften the water by Dr. Clark's process.
Castle Howard, Yorkshire.	Octr. 1858	22 1/10	4 3/10	29¼	10¾	Spring water from the oolitic formation.	
The Caterham Spring Water Company.	Augt. 1861	18¾	3½	26¾	9¾	Spring water from the chalk formation.	
Herbert Hospital Water Supply.	Augt. 1865	21	7½	28½	—	Spring water from the chalk formation, supplied by the Kent Water Company.	Constructed for the Government, and by order of the War Office.
The Chiltern Hills Spring Water Company Limited.	Expected to be opened July 1867.	13¾	2¾	20¼	8¾	Spring water from the chalk formation.	

NOTE.—One grain of chalk dissolved in a gallon of water is one degree of hardness. In like manner four grains per gallon would produce four degrees of hardness, 10 grains 10 degrees, and so on.

Dr. H. Letheby.

29 May 1867.

Dr. HENRY LETHEBY examined.

3859. (*Chairman.*) You are, I believe, Professor of Chemistry in the London Hospital, and also Medical Officer of Health to the Corporation of the City of London?—Yes, I am.

3860. Your attention has necessarily been directed to the supply of pure water and to the effects of impure water?—Yes, very much so, not only in London, but also in most of the large towns of England.

3861. Can you give us any information as to the present condition of the water supplied to the metropolis?—Yes, I think I can. I may say in the first place that I have examined the water of the East London Company from the year 1861, twice every month until the present time, that I have made similar analysis of the water supplied by the New River Company every month from the year 1863, and a like analysis every month of the Kent water from that time, and in the year 1864 I was requested by the Medical Officers of Health of London, associated as they are under the name of the Metropolis Association of Medical Officers of Health, to make an analysis every month of the water supplied by the whole of the metropolitan companies. Those results have been regularly published.

3862. Can you put in the results of those analyses so made?—I can put before the Commission the results of the analyses in a general way.

3863. Do you know the general properties of the water supplied by the metropolitan companies, first from the Thames Waterworks above Hampton, the West Middlesex, the Grand Junction, the Southwark and Vauxhall, the Lambeth, the Chelsea, the New River (Lea springs and wells), and the East London?—Yes, that comprises all except the Kent Water Company, which supplies a very small portion of the metropolis?

3864. Is that water taken from the Ravensbourne?—It was formerly; it is not now; it is taken entirely from wells; not a drop is taken from the Ravensbourne.

3865. You think there is none of the Ravensbourne water in it?—None whatever. I suppose they have eight or nine wells, and they take the whole of their water from them. You will see that the first of these tables which I will hand in represents the general properties of the waters supplied to this metropolis in the month of January last, and it will be important to compare the results with the analyses made in the corresponding month of 1856, at the instance of Mr. Cowper who was then at the head of the Board of Works, and also the results of a like inquiry that was instituted at the request of the Government by a commission of chemists, namely, Professor Hofmann, Dr. Miller, and Professor Graham, in the month of January 1851. We are therefore in a condition by those comparisons to form some notion of the quality of water at each of those several periods of inquiry, it happening that the inquiries were made in each case in the month of January.

3866. Are those tables made up to the present year?—Yes, all of them. With regard to Table No. 1, that will show the degrees of hardness of the several waters, ranging, as you will perceive, from about 13 to 14½ degrees. It will also show the quantity of gases dissolved in the water, the object of that being to ascertain whether the waters are well aerated or not, which is a very important consideration, in a sanitary point of view. The proportion of gases dissolved in water ranges from about 13 to 14 cubic inches, and the most that water can take up is 15 cubic inches. That shows also that the proportion of oxygen contained in the water is very large, considerably more than is necessary to oxidise the organic matter, but if you look at the last line but two you will find the total quantity of oxygen required to oxidize the organic matter in the water, and in the last line but one there is the quantity of oxygen dissolved in the water, and you will perceive that it is at least five times as much as is necessary for the oxidisation of organic matter. The conclusion from that is that the water is remarkably well ærated; in fact, it is so exceedingly well ærated that we find in its passage along the public pipes or mains the atmospheric oxygen dissolved in it really does effect the oxidisation of organic matter, though the water is shut completely out of the atmosphere, which is a proof of the good aeration of the water. Then the last line of the table represents the quantity of am-

monia in a gallon of water, and that comes to 0·003 of a grain, which is further proof that there is no organic decomposition in the water. (*The witness delivered in the Table, which is the same as Table* 1. *in Appendix A G.*)

3867. Will you now explain the second table?—The second table represents the individual constituents of the water of each of those companies. You will perceive that in round numbers the total quantity of solid matter in a gallon of water ranges from 19¼ grains in the Thames at Hampton to nearly 24 grains which we find in the East London water, and of this proportion the organic matter, as determined by the process called incineration, ranges from about three-tenths of a grain in the East London water to about 1¼ grain in the Lambeth water. But this matter called "loss by incineration" represents other things besides organic matter. The conclusion from it is that the waters are not overcharged with saline matter, for the proportion is no more than is generally found in river waters running from a chalk district. (*The witness delivered in the Table, which is the same as Table* 2. *in Appendix A G.*)

3868. Now, will you explain Table No. 3?—The next Table, No. 3, will probably be more important to this Commission, because it represents the composition of the waters in every month of the year, during the years 1865 and 1866, showing the total proportions of solid matter in a gallon of each of the waters, also the quantity of organic and other volatile matters lost by incineration, and also the quantity of oxygen required to oxidise organic and other matter per gallon. (*The witness delivered in the Table, which is the same as Table No.* 3. *in Appendix A G.*)

3869. You do not start, I believe, with any standard in those tables?—There is no standard with regard to the quality of the water. It is scarcely possible to take any water which can be regarded as a standard; generally speaking, we may say that a water of over 10 degrees of hardness may be regarded as on the side of a hard water, and when below 10 degrees of hardness it may be regarded as on the side of a soft water, and so on in proportion to those degrees.

3870. The Loch Katrine water, I believe, is generally referred to as unexceptionable?—Loch Katrine water is undoubtedly very soft water, but on considering a great number of circumstances connected with Loch Katrine water, as the liability of it to organic contamination, and the tendency of it like all such waters to act upon lead, and the circumstance that it is so frequently tainted with peaty matter, there are very important objections to its use in such a city as London.

3871. (*Chairman.*) Do you think that peaty water is objectionable to health?—No, but it is so objectionable on account of its colour that Londoners would not drink it. I do not mean that the quantity of peaty matter found in the Loch Katrine water would be injurious to health, but I am satisfied, from my own experience and from the reports of Commissions appointed on the continent with regard to the water supply of Paris and Vienna, that the inhabitants of a large capital, using water for domestic and not for manufacturing purposes, would not drink such water.

3872. They would prefer a clear, pure, chalk water?—Unquestionably.

3873. You will find that the last table of this series shows the composition of the pump waters of the City of London, and you will notice how much saline matter is in them, and yet so strong is the public instinct for waters containing saline matters that we could scarcely keep people from drinking those waters during the time of cholera, when such water was considered to be very dangerous, for the pumps were close to the sewers, and when to prevent their being used the handles were taken from the pumps, the outcry was so great that we were obliged to restore them.

3874. That arises from a natural preference in favour of what is called pump or spring water?—It does. The saline matter which is contained in such waters has a tendency to give them an agreeable taste, and moreover they are generally well aerated waters; they are also free from colour, and are cool and grateful to the palate, and on that account there is as it were an instinctive liking for such water.

3875. Do you not think that that arises more from the impression in the public mind that pump waters (I am now speaking of the popular impression) are the best, and persons therefore resort to pump water as that which is the most agreeable for drinking purposes rather than from any special quality of that water as detected in the act of drinking?—No. I should be rather disposed to think, from the public statements which have been made with respect to the dangerous qualities of the pump water of this metropolis, that the public feeling would be that such water is not proper to drink, and that persons are induced to take those waters by their liking for the agreeable qualities of them; and really the preference for those waters depends not on the notion that pump waters are better than others, but on the fact that they are more agreeable to the palate. With the permission of the Commission I will hand in the following table, which shows the composition of the water furnished by the City pumps. (*The witness put in a Table, which is the same as Table No.* 6. *of Appendix A G.*)

3876. (*Mr. Prestwich.*) Do you think that the great bulk of the people who use this pump water in London know the actual origin of the water?—I have frequently reported on the subject, and notices have been put upon the pumps stating, "This is a "dangerous pump, and the water ought not to be "drunk," and indeed the greatest pains have been taken to inform people of the fact that those pump waters ought not to be drunk, but nevertheless they will drink them.

3877. From what I know of the use of these pump waters in the City, it seems that nothing is known about the quality of the waters, that they are sought for because they are so extremely cool and sparkling, and pleasant to drink, and very agreeable to the eye and to the palate also, quite apart from any knowledge of the quality of the water?—Quite so. The quality of the water itself as regards its agreeable appearance, its sparkling character, its cool taste, and so on, is what gives to them a liking for such water, but notwithstanding that we have informed them of the danger of using such water, they will still drink it. Four times have I reported, and my reports have been pretty well circulated, as to the danger of the pumps of the City, and yet the public continue to use them.

3878. Only those persons who went to the pump would be aware of this notice that had been posted up, the greater part of the people who use the water in the City send to the pump for the water, and it is brought by their servants?—There is a great deal of publicity given to the reports of the Commissioners of Sewers in the City of London, partly by reason of the local paper, and partly by the extensive circulation of the reports themselves, that I can hardly think the people are ignorant of the qualities of this water.

3879. (*Chairman.*) Unhappily that the most important and valuable reports are disregarded by the public you have evidence in the City as elsewhere?—Yes.

3879. Having regard to those waters, and the several tests which you have yourself made, what is your opinion generally of the water supplied to this metropolis?—My opinion is founded in the first place upon the actual analyses of the waters over a long period of time, monthly analyses; it is founded in the next place upon an observation of the use of those waters very extensively, and I am bound to admit that there is no evidence whatsoever that those waters are in any way objectionable as a public supply. I am now speaking of the whole of the metropolitan waters.

3880. Notwithstanding the amount of organic im-

Dr. H. Letheby.

29 May 1867.

purity that is your opinion?—The organic impurities are not large in the London waters. The loss by incineration, although a grain, is not regarded as a serious quantity, because the loss by incineration represents a great deal more than the organic impurities. I will now hand in Table No. 4 (*see Appendix A G.*)

3881. Have you any means of contrasting those tests which you have made with the tests made prior to the companies going up to take their supplies at a higher point?—Yes, I have. If you will take the Table No. 4 of this series which I have just handed in you will see the quality of the water in 1851, when they were taking their supplies below Teddington Lock, and also in 1856 when they had just taken their supplies above Teddington Lock, for in 1856 the Honourable Mr. Cowper called for this inquiry to ascertain how the Act of Parliament of 1852, which compelled the companies to go above Teddington Lock, had worked, and then there is also the result of our inquiry in 1867. If you will look at that table you will see improvements in the quality of the waters at each of those periods. In 1851 the total quantity of solid matter in a gallon of water, taking the average of all the Thames Companies, was 21·43, in 1856 it was 21·04, and in 1867 19·48. The next set of facts are the most important with regard to the organic and other volatile matter per gallon. In 1851 the chemical commission reported that the average proportion of organic and other matter per gallon was $2\frac{1}{2}$ grains as nearly as possible. One of those chemists was again engaged in the inquiry in 1856, viz., Professor Hofmann, and he reports the quantity to be 1·31.

3882. It had improved in five years from 2·46 to 1·31?—Yes, and Professor Hofmann in commenting on that fact, and perceiving that it was common to every one of the water companies, says it is a proof beyond all question of the water having improved in that interval, and that it is not an accident, for the experiments were made on both occasions in the same laboratory and by the same people, and therefore there was nothing in those results that could vitiate or in anyway affect the conclusion, viz., that those waters had notably improved between those two periods. I will read his words from his report to the Right Honourable Mr. Cowper. "The total amount of solid "matter in the two years likewise exhibits but unim- "portant fluctuations." Then he puts in italics "*A "very considerable diminution, however, is obtained in "the amount of organic matter.*" In fact in 1856 the waters supplied to the metropolis contained not more than one half of the organic matter which was present in the year 1851. This result is certainly not accidental. The diminution is not merely an average result but uniformly observed throughout. The waters examined in 1851 were taken in January, those investigated in 1856, partly in January and partly in April. The diminution of the organic matter cannot therefore be due to the influence of the season, nor can it be due to any difference in the mode of determining the organic matter in 1851 and 1856. These determinations were made by exactly the same method, for it so happened that the analytical part of the inquiry in 1858 which refers to the organic matter was likewise made in the laboratory in the Royal College of Chemistry. Then he goes on to explain why the organic matter has diminished, and he says that it is by going farther up the river and adopting processes of filtration. If you look at the year 1867 you will observe that the volatile matters amount to 0·98 or less than a grain per gallon. The hardness is reduced also but not much. In 1851 the degree of hardness of Thames water was 14·4, in 1856 it was 13·5, and in 1867 13·3. We have therefore in this table a comparison of the analytical results on the three several occasion when there have been inquiries into the water supplied to the metropolis.

3883. You will observe that the Lambeth Waterworks water contained a larger quantity of organic matter in the year 1867 than in the year 1856?—Yes, in 1856 it was 1·03 and in 1867 it was 1·24.

3884. (*Mr. Harrison.*) The East London water from being 4·12 in 1851 was reduced to 1·14 in 1856 and 0·30 in 1867?—Yes.

3885. (*Mr. Prestwich.*) At what period of the year?—All the samples were taken in January.

3886. Is January about the period of the year when water contains the largest amount of organic impurity?—Yes, it is. You will see in table 3 that the months of the year when we have the largest proportion of saline matter in a gallon, in the case of all the companies, are November, December, January, and February. Those are the wet periods of the year, and during wet weather there is the maximum of solid in the water, whereas in the warm summer months of July, August, and September we have less solid matter in the water than at any other time of the year. At that time the amount is a little under 17 grains in a gallon, and during the wet winter months it is about 21 grains in a gallon.

3887. (*Chairman.*) Then it is evident from those tests that from the year 1851 the water had greatly improved in 1856 and still more so in 1867?—Yes, those investigations show that.

3888. And in your judgment the water now supplied as a whole is unobjectionable?—That is my opinion.

3889. With regard to the condition of the Thames water, you are aware, are you not, that the Conservancy Board under the powers recently granted by Parliament, have power to serve notice upon the several authorities on the Thames up to and including Oxford, to intercept all the sewage and filth which now flows into the Thames?—Yes I am aware of that. I hold in my hand their Act of Parliament.

3890. And they have given a certain number of months to enable those authorities to make that interception, subject of course to an appeal for extension of time if necessary?—Yes.

3891. When that interception takes place, will the water of the Thames in your judgment be greatly improved?—I do not think that it will be much improved. Not but that I am quite ready to admit that the discharge of sewage into such a river is a most improper thing, but considering the powerfully oxydising influence of water upon sewage the many agencies which are at work destroying it, the power of precipitation, the using of it up by vegetables and aquatic plants and by fish, and above all by the power of oxydization, I think that none of the sewage discharged into the Thames can at the present moment be discovered at Hampton, but nevertheless it is very possible that there may be a still further improvement of the Thames water by the adoption of these measures. Certainly there will be an improvement in this manner that if the discharge of the sewage into the Thames were to go on increasing during the next 20 or 30 years, as it has been during the last 20 or 30, we should then probably have such an excess of sewage in the water of the Thames as would render it very unwholesome. But at the present moment I cannot perceive through the most refined chemical processes the existence of a particle of sewage in the water at Hampton where the Thames Companies take their supply.

3892. You have had your attention directed, have you not, to the fact that the river running through the town of Leicester some years ago was greatly polluted from the discharge of sewage, and that the plants and fish were destroyed for three or four miles down the river?—Yes, I know it well.

3893. At the end of the third or fourth mile plants began to revive, fish were seen active, and the water appeared in its normal condition?—Yes.

3894. Have you at all ascertained in what length of time or distance polluted matter will be decomposed and transformed in its chemical qualities; for example, supposing we had the sewage from Richmond poured into the Thames, how far down the river would it be lost as sewage and broken up into other chemical elements?—I have made a very great number of chemical experiments to determine that. I have examined most of the rivers in England, and this is the conclusion

that has been come to not only in my mind but in the minds of all the engineers who have devoted their attention to the subject, that if ordinary sewage containing we will say nearly 100 grains of solid matter per gallon, such as our London sewage, out of which probably something like 14 or 15 grains are organic, be mixed with twenty times its bulk of the ordinary river water and flows a dozen miles or so, there is not a particle of that sewage to be discovered by any chemical processes.

3895. When you use the word flow do you mean at any given rate, or simply the fact of its flowing?—I do not think that the rate affects it so much because if it flows fast and the time is shortened the agitation makes up for the delay of the time. If it is flowing slower, and therefore not likely to be so much agitated and brought into contact with the atmosphere, there is a longer time for the effect, and I do not think a greater rate of flow a matter of very great difference in that respect.

3896. (*Col. Harness.*) If it did not flow at all what would the effect be?—That does not seem to make much difference. If we place water in a laboratory and stand it in an open vessel in which it is not moving at all we find, in the course we will say of something like 24 hours, that oxydization has taken place, and we cannot then discover it. It seems to me that river water contains in itself enough oxygen dissolved to oxydize and dissolve the organic matter of sewage provided you give it a few hours to act.

3897. (*Chairman.*) Is it the fact that sewage discharged into a river to the extent of 5 per cent. of its bulk will at the end of the seventh mile lose its character as sewage and be broken up into other elements which will not be injurious to the public health?—That is the result of my observation and experiments.

3898. (*Mr. Harrison.*) Taking the case of the cholera disease and the discharges from the human body being mixed up with the sewage, do you consider that any germs of that disease would be carried down in the water?—At the present moment we do not know what the germs of the disease are. If the germs of the disease be decomposing matter then I do not think that they would exist in the water; but if the germs of the disease be living matter then it is possible that they may exist in the water, but as nobody as far as I am informed can tell us what the germs of cholera are it would be premature for me or anybody to theorize as to the probability or the possibility of their existing in the water.

3899. (*Chairman.*) That would depend upon the amount of resistance, because we had an account in a French publication recently that a seed after being boiled for four hours vegetated notwithstanding?—I have heard of such cases, but I am very sceptical.

3900. (*Mr. Harrison.*) Have you heard the opinion stated that in the case of the cholera at Southampton the disease had been conveyed by means of the sewage water?—I think it is very likely indeed, my own impression is that the matter discharged from cholera patients is the immediate agent of infection, that if you will take pains to destroy it you will prevent the disease from progressing. Such matters are likely to get into running streams and rivers and they are very likely to get from the drains into the public wells. We have had so many instances of cholera having been traced to such polluted water that I have no doubt that those discharges getting into the water may produce disease, but then comes the question of the extent to which dilution takes place in the rivers, about which I can give no opinion.

3901. (*Chairman.*) You are aware that it has been alleged that the main cause of the cholera in the east of London was due to the water supply, do you entertain that opinion?—No, I entertain the opposite opinion. It was a matter of duty with me to investigate the whole of the circumstances connected with the East London supply. In the first place it was supplied to the hospital to which I am attached, in the next place it was supplied to the eastern division of the city, where, as officer of health, it was my duty to look well into the matter, and in the third place I had a general interest in it scientifically, apart from any official connexion with the subject, and I was very desirous to ascertain whether or not the water had been in any way concerned in the propagation of the disease. I therefore investigated it very fully.

3902. Are there two distinct waters supplied to that district?—Yes, but I will tell you this with regard to it, there is hardly anybody who can say, except in certain parts of the East London Companies district, whether the water had come from the reservoir at Old Ford or whether it had been received from the filter beds at the Lea, which is considered to be a good water, for the water was oscillating backwards and forwards in the mains in such a manner that the engineer himself had no knowledge what water was in any main at any particular time. But on the other hand there are places at which Old Ford water, and that water alone, is supplied, namely, Stamford Hill, Upper Clapton, Walthamstow, Woodford, Wanstead, Leytonstone, North Woolwich, and Silvertown, and excepting the two last-named places there was no cholera in any of them; there was a little in Silvertown towards the end of the epidemic, but the other places were free from it, and those were the only places where we actually knew that that water did go.

3903. Dr. Farr gave evidence before this Commission to the effect that wherever this particular water was supplied, the cholera was most prevalent in that district, and that they could mark it even to the centre of the street, one side of the street being supplied with one water, and the other with another, and that the bad water was marked by the progress of cholera most distinctly throughout the district?—I do not concur in that opinion, and moreover I may say that my brother medical officers of health who have had experience of the cholera in all those districts do not concur in it. I could read an extract from their reports which would show that they do not believe a word of it, and there is no proof of it. It is an assumption to begin with that the water was received from the Old Ford reservoir.

3904. (*Sir B. Phillips.*) Do you think the present supply of water to the London people is wholesome water?—I do, a thoroughly wholesome water.

3905. The chairman has mentioned to you the evidence which Dr. Farr has given in reference to the action of the water upon the cholera patients in the east of London. You have told us that you do not confirm that statement, in other words, that you do not believe it?—I not only do not confirm it, but I know that it is not so.

3906. You do not think that the cholera was induced by the water supplied to the people at the east end of London?—I am sure it was not. I am satisfied from my inquiries that it did not do so, that it had no more to do with the propagation of cholera than the commercial gas had, for there was the like coincidence of the Commercial Gas Company's district being exactly the cholera field, just as the district of the East London water supply was the cholera field.

3907. You visited that particular district, did you not?—Yes, I went into it all. In one division of the City there were 62 deaths in the district supplied by the East London and the New River Companies. Now the New River Company's water is above suspicion, nevertheless, of those 62 deaths in that district, there was only a single house in which the East London water was taken; all the rest were supplied with New River water. At my own hospital, the London Hospital, we had nearly 500 people in the hospital, and they drank nothing but East London water. Those patients may be looked upon as people most susceptible of disease, but we had not a single case of cholera arising in the hospital, though we had such a large number brought in as patients.

3908. (*Chairman.*) You know that the district board alleged that there were two distinct waters supplied to that area. What water was supplied to

Dr. H. Letheby.

29 May 1867.

your hospital?—I have consulted Mr. Greaves, the engineer of the East London Water Company, upon the matter, and he cannot tell you at any time in the day whether it is the Old Ford Reservoir water that is supplied, or whether it is Lea Bridge water, for it is oscillating in the pipes backwards and forwards; but Dr. Farr has taken it for granted that the Old Ford reservoir water was there, but even if it were there, I tell you that it did not produce the disease. I will take another instance, which is a very strong one, I think, in proof of the non-connexion of the water with the cholera epidemic. If this water had been charged, at any particular time, with this cholera poison, supposing, for one moment that that poison were arsenic or alcohol in the water, distributed over the district, there would be some uniformity in the time of the outbreak, or manifestation of its action over the district, but a month elapsed in several of the districts and no outbreak appeared where this suspected water was being supplied. There is no coincidence of time in the outbreak, and there is no coincidence in the intensity of the disease or in its duration along that district. In the next place, people taking that water and drinking it in its unfiltered state did not get the cholera, while the cholera affected people in that district who did not take that water. At one of the city of London workhouses, the City of London Union Workhouse which is in the Bow Road, they did not take a drop of the East London water, but drank the water from their deep well. I receive, and did receive every week, a return of the progress of disease in that workhouse, and they were decimated by the cholera. Another workhouse, namely, the East London Union, has its workhouse at Hackney where they do take that water, there was not a case of disease there; and then at Stamford Hill, and those places where no other water but the Old Ford reservoir water was pumped—for they have a special power to send it to those places—there was no cholera. I say, therefore, it is a very hasty conclusion, because of the coincidence of the outbreak of disease in that locality with a certain water distribution, to say that the water has been the cause of the disease. Mr. Bazalgette wrote at the time to Dr. Farr, to say that that was unfortunately the very locality in which the main drainage operations were not completed, and you will find that according to the level of the district, high or low, so was the intensity of the disease, although the water was taken equally in all those places. I have no prejudices upon that matter, but it was my duty, as officer of health, to investigate this question of water supply, and the conclusion which has forced itself upon my mind as it has upon the mind of every officer of health, except one, is that the water supply has had no connexion with it.

3909. You are not connected, are you, with any water company?—Not at all. I analyze the water, and I supply the results to the medical officers of health, and I supply the results to three or four companies upon the payment merely of the expense incurred by it, but I am not in any way connected with the water companies beyond that.

3910. (*Mr. Harrison.*) In the case of the previous outbreak of cholera, in 1854, was there any distinct connexion between the cholera and the water supplied then?—There was, as it appears from Dr. Snow's investigations, and those investigations were, I admit, to my mind so conclusive, that I had no doubt that the foulness of the water at that time had a good deal to do with the propagation of the disease. But it has been found since that the company's pipes were running in such an intricate manner in the district that the companies themselves did not know which houses they supplied with water. The evidence upon which Dr. Snow founded his conclusions are open to that doubt, that although he got proofs of such and such water companies having supplied the water, yet the whole thing was in such confusion that no one knew what water was given to the houses of any particular district.

3911. Was it not the case that at one time one water company would just open the ground and put a tap into its neighbour's pipe?—Yes.

3912. (*Chairman.*) Apart from the question of the quality of the water, has your attention been directed to the question of the constant, as compared with the intermittent system of supply?—Yes, it has.

3913. What are your views upon that subject?—As an abstract question, there can be no doubt that the constant supply is a very advantageous thing to the public, chiefly because they would get their water cooler, more grateful, less liable to the pollution to which it is now subject after it is delivered by the water companies, and, if the question really turned upon poor people's houses, I should say that the constant supply to them, whether it be in a court by a standpipe, or whether it be in their own yards by a standpipe, would be a boon, the good of which is hardly to be calculated.

3914. You have visited every part of the City, and, as we all know, there are some parts of the City where a very large number of poor are congregated; do you find that the receptacles in which the water is kept are frequently the cause of great mischief to the health of the inhabitants, by standing near to cesspools or privies?—Yes, by standing in the neighbourhood of privies, in dirty cellars, and so on, no doubt it becomes much polluted.

3915. I suppose that the water itself would take up any gas that might be generated in that locality?—It would do so. It does not take it up anything like so fast as soft water. Soft water is very prone to the absorption of gases, almost immediately, but hard water is not, from the circumstance that hard water contains such a large quantity already dissolved in it that it shuts out, as it were, the other foul gases. As I say, in the poor people's houses it would be an incalculable benefit; but with regard to the better class of houses it is a matter open to doubt as to whether or not a constant supply should be granted without a cistern of some kind or other to provide against what must happen more or less frequently in the derangements of the mains, and the shutting off of the water, or something of that sort, and it would necessitate a complete alteration in the present mode in which the fittings of the houses are managed.

3916. (*Sir B. Phillips.*) Were not standcocks supplied in the City during the cholera in different parts of the courts of London?—Yes, in almost all the public courts where it was thought it would be advantageous, and where we did away with the pumps upon which people had been relying for much of the water they drank. The Commissioners of Sewers thought it right and proper that they should supply the poor with water, and they put up standpipes, and both from the East London and the New River Companies we encountered no difficulty whatever; they readily gave us the opportunity of putting up those standpipes.

3917. Have they been withdrawn?—No, they are most of them there; but it is a new thing, and the children play with them to such an extent, and we have had so many memorials from the inhabitants to take them away that we hardly know what to do at the present moment.

3918. (*Chairman.*) During the time that they were in use they were accompanied with a great advantage to the people?—Yes, I think so. There is a table to which I would wish to direct the attention of the Commission, Table No. 5. I have classified in this table the composition of the water supplied to most of the towns in England, giving an account of the appearance of the water when it is examined in a long glass tube; next, the quantity of solid matter contained in a gallon; next the amount of organic matter; then the oxygen required to oxidise the organic matter, then the ammonia, then the hardness, and then the population of each of those towns, and lastly the mortality per 1,000. The object of this is to ascertain whether there is any relation whatever between the mortality of a district and the quality of its water supply, and you will find at the bottom, under the line that where the water

supplied to the towns is over 10 degrees of hardness, which I look upon as on the side of a hardness, the mortality is only 22·2 per 1,000 of the population, whereas in all the towns with soft water, that is with water under 10 degrees of hardness, the mortality is 26 per 1,000, and with the metropolitan water it is 23 per 1,000. I do not pretend to say that the quality of this water has had anything to do with the mortality, but there is this important fact, which comes from the examination of the table, that certainly soft water does not improve the health of the people, and that many of those towns are very comparable. I take Sheffield and Birmingham to be very comparable with regard to the character of the inhabitants, but look at the mortality in the two places. Birmingham has nearly the hardest water that we have in England, and Sheffield has one of the softest waters, nevertheless the mortality of Birmingham is only 24 in the 1,000, whereas you will find that the mortality of Sheffield is 26·2 per 1,000. I do not mean to say that the water has anything to do with it, but it shows that there is no evidence of soft water so benefiting the health of the people as to reduce the death-rate. (*The witness delivered in the Table, which is the same as Table No. 5. in Appendix A G.*)

3919. From your large experience, you would scarcely be prepared to say that the mere question of the supply of good or bad water would actually in itself determine the mortality of a place; there are other circumstances, are there not, which must be taken in account?—Yes, certainly.

3920. For example, take the condition of Glasgow, where they have an unexceptionable water, yet where there is a lack of all other sanitary arrangements, drainage of the town and so on, that might of themselves be a sufficient cause for the increased mortality there?—Yes, and it is one of the largest,—27 per 1,000 is the mortality of Glasgow.

3921. (*Sir B. Phillips.*) The smallest amount of mortality in this table appears to be at Croydon?—Yes; and it is a hard water they have at Croydon.

3922. Was there not a serious outbreak of fever there some time ago?—That was before the water supply. That was at the time when they began the drainage by pipe-drains, and in consequence of the bad ventilation of those drains the gases were all forced into the houses of the people, and a tremendous fever broke out. I have had occasion twice to inquire into the outbreak of fever at Croydon, and I have no doubt it was traceable to that. The pipe drainage system is a system which, unless perfectly carried out and the ventilation is good, is so tight that the gases cannot get out, and they therefore force their way through the valves of the water-closets and get into the houses, and an outbreak of fever ensues.

3923. (*Chairman.*) The best proof of that is, that immediately the alteration took place you found an improvement in the public health?—Yes.

3924. (*Mr. Harrison.*) In Sheffield is not the average of age less in consequence of the knife-grinding that is carried on there?—That may be so.

3925. (*Mr. Prestwich.*) This return appears to be made up to 1861, what was your reason for that?—In every instance the waters which they are taking now were taken in each of those towns in the year 1861, but I am not able to say what the population of those towns at the present time is, nor what the death rate is. I am obliged to take the only reliable information I can get, namely the mortality returns as well as the population in 1861, for they are the only ones that are accessible, but all those towns had the same water in 1861.

3926. Has not the soft water supply to Glasgow been since 1861?—No, it was before 1861.

3927. What do you consider to be a sufficient supply per head of the population?—I think that the experience of engineers generally accords with my own experience of the matter, and I should say that 20 gallons per head for all purposes is a very good and sufficient supply.

3928. (*Chairman.*) Do you mean for all purposes other than manufactures?—No; I mean for all purposes. Taking an average town, taking London for instance, where manufacturing operations are not large, 20 gallons per head is sufficient for London, including everything. I take it that about 16 gallons of that would in all probability be used for domestic purposes, and probably three or four gallons would be used for other purposes; but in towns where the constant system is adopted, and where the management is very well regulated, and the public are prevented from wasting the water, we find upon the average that about 18 gallons is that which is used for all purposes; for instance, that is the case in Nottingham and Norwich. Therefore we may look upon 20 gallons as a very fair quantity. At the present time, I believe, the metropolitan companies are supplying as near as possible 30 gallons.

3929. (*Mr. Harrison.*) In Table No. 4 you take 30·9 as the present supply, do you not?—Yes. The last three columns give the quantity supplied per day by each company in 1851, 1856, and 1867, and then at the bottom of the table you will find that in 1851, the population being so many, the average was 19·4 gallons per head. In 1856 it was 30·2 gallons per head; and in 1867 I may say it is 30·9.

3930. (*Chairman.*) Does your estimate of 20 gallons per head include all necessary supply for street purposes and fires, and every other purpose?—Yes, everything.

3931. (*Mr. Prestwich.*) Apart from the question of organic contamination, about which there can be no doubt, have you any evidence with respect to which is the best water for drinking purposes, soft or hard water?—A moderately hard water is best.

3932. Have you any evidence bearing upon that?—Yes, I have. I have evidence derived from my own inquiries and my own experience, and the evidence of the continental commissions which have been appointed to inquire into the best supply for the large cities of the continent. I will take the case of Paris. The commission appointed a few years ago had opportunities of gathering water from granite districts and from millstone grit districts, I believe, as well as from hard chalk water districts; and upon investigating the facts of the case very carefully the French commission concluded that the evidence went to show that the men were finer grown and that less conscripts were refused upon the ground of insufficient stature or something of that kind in the hard water districts than in the soft water districts; and after much consideration of the subject, they recommended the municipality of Paris to take a water which is almost identically the same as the water of London. Very recently I have received from the government of Vienna the report of a commission appointed to investigate the distribution of water in Vienna, and there again they have abandoned soft water, and have taken to a moderately hard water for two reasons, first, that the evidence goes to show that the men are better formed, that the bones are stronger and better formed, and that there is better health in moderately hard water districts than there is in soft water districts; and, secondly, that the public prejudices against water tainted with peaty matter are so great that a large city should never draw its supply from a soft water district.

3933. (*Chairman.*) Lime is not necessary in water to supply bone, is it?—You cannot say that it is not; probably there is no evidence to show that it is, but there is no evidence certainly to the contrary. Our bones must be made of lime. It is true that milk and the common articles of diet contain generally speaking enough lime to form the young tissues in that respect, but you cannot say how much a hard water or the lime of a moderately hard water contributes to it. And if we are to be guided by what may be termed the Providential evidences with respect to it, $\frac{4}{5}$ths at least of the earth's surface being calcareous districts, that is to say, districts supplying hard water, one would think that if it had been the case that soft

Dr. H. Letheby.

29 May 1867.

water was better than hard, we should have had it more abundantly distributed to us than it is. There are notions abroad that hard waters have a tendency to produce gravel, but I have investigated that subject and there is not an instance of gravel or any surgical affection of the same kind that I can trace to hard water. My own opinion is that water of between 10 and 15 degrees of hardness is in every respect the most proper water for the supply of a city. In the case of large manufacturing towns where the water is used to a very large extent in steam engines and for bleaching and dyeing purposes for which soft water is required, that would affect my conclusions, but in large cities such as London, Paris, Vienna, or Berlin, I have no doubt in my own mind that water of between 10 and 15 degrees of hardness is the proper water, provided that upon being boiled it would be reduced to about 4 degrees of hardness. It is 5 degrees of hardness in any kitchen boiler that you like to take it from in London and that is sufficiently soft for tea, for washing purposes, and for everything that may be required in ordinary domestic use. And in addition to that the water is agreeable, it is almost always colourless, bright, sparkling, and agreeable to the palate, and as far as I know may contribute something towards the nourishment of the tissues.

3934. In expressing those opinions your view would be clearly against the notion of going any distance to obtain a supply of water to the metropolis?—I would not only not go to a great distance, but I would say that if soft water were next door to you, if the Thames itself were soft water like that which is proposed to be supplied to London from the lakes, and there were found in the chalk of the neighbourhood a harder water like that we are now using I should unquestionably advise the harder water to be taken.

3935. Even at additional cost?—Yes, even if the soft were close to you and if the hard water would cost more. I call it hard merely comparatively. I mean water that would range from 10 degrees to about 15 or 16. Beyond that it becomes too hard particularly if it is a sellinitic hardness, if it is sulphate of lime in place of carbonate of lime under such circumstances it becomes objectionable.

3936. (*Mr. Harrison.*) Taking it that the average of hardness of the waters of the Thames companies is only 13·3° that quite comes within your limits?—It does; and I am of opinion from a large experience of the matter, not only from chemically analyzing the water but from observing the effect of it upon the public health, that there is hardly a city in Europe so well supplied with water either as regards quantity or quality as the city of London.

3937. You would not consider it necessary according to your view to apply Dr. Clark's process to this water?—I should not, for I think it would be injurious. If the water were softened by Clark's process, it is not only an expensive process, and as far as I know a very difficult process to carry out on a large scale, for I know of no instance in which more than half a million gallons a day have been softened, but apart from all that the softening process renders the water very liable to attack lead. It did so at Plumpstead to such a degree that they were obliged to replace I believe the whole of the cisterns or nearly so at Plumpstead, at the cost of the Local Board. The carbonate of lime that was in the water was thrown down in the pipes by a process of crystallization afterwards so as to block up the pipes for miles in length. Whenever there is a bend in a pipe it offers a little hindrance to the movement of the water, and the particles as it were strike together, and the carbonate of lime begins to be deposited directly. I have seen pipes become almost entirely shut up with it a long distance from the works.

3938. (*Mr. Prestwich.*) Are you acquainted with the evidence which was given before the board of health, with regard to the economy in the use of soft water some years ago?—Yes.

3939. What opinion have you formed with regard to that?—My opinion is, that it is very much exaggerated, and that exactly coincides with the opinion which the chemical Commissioners, Messrs. Hofmann, Graham, and Miller, formed of it, that whilst one grain of carbonate of lime will actually destroy the detergent properties of 10 grains of soap (and they looked at it from that point of view) it would seem that there is a very large loss of soap, but when you consider that all water before it is used for detergent purposes is heated and reduced to about four degrees of hardness, it very considerably reduces the amount of soap destroyed. Those Commissioners in their report have stated what they consider would be about the quantity of soap destroyed in ordinary washing operations, and in washing flannels and so on, and they have proved beyond all question that the proportion is so small as not to be deserving of consideration. I think therefore that those statements which were made by the old board of health upon that subject, were founded upon wrong premises. They were founded upon the supposition that water was always taken of the degree of hardness that it has in its unboiled condition.

3940. You would separate the permanent from the temporary degrees of hardness?—Yes, the permanent hardness being that upon which I found my calculations, while the non-permanent is that upon which the board of health founded their calculations; and this makes a good deal of difference in the result.

3941. (*Sir B. Phillips.*) Have you seen the scheme of Mr. Bateman?—Yes, I have seen them all. I think there are five or six that have been sent to me.

3942. Supposing that water could be brought from the lakes, and delivered to London at the same cost as the water is now supplied from the Lea and from the Thames, do you think it would be desirable to avail ourselves of such a supply?—I have already said that if we had next door to us instead of at the lakes of Cumberland soft water, and we had the water supplied by our rivers flowing from the chalk districts, I would recommend without hesitation the use of the hard water in preference to the soft water. I have had occasion to examine and analyse very carefully the waters that are flowing from Loch Katrine into Glasgow, and I know the quantity of carbonate of lime that is taken up by those waters in their flow along the channel from the Loch to the city of Glasgow. It amounts to about 500 tons of carbonate of lime are taken up from that channel every year: what will be the end of it in the course of years I do not know. All that carbonate of lime comes, I daresay, from the mortar that joins the stones together, and one would think that it would bring the whole thing to pieces at last.

3943. (*Mr. Harrison.*) It appears that in 1851 the quantity per head was 19·4 gallons of water per day in London. To what do you attribute the large increase which has taken place since that time?—I do not know, except it may be that the companies have perceived the necessity for extending the supply. There has been, as far as I know, no pressure put upon the companies to do it. I do not know that in the course of any inquiries before any parliamentary committees or any Royal Commissions the question of the quantity of water has been raised; therefore I take it that this must have been the voluntary act of the companies.

3944. Has not a great deal of it arisen from the increase in the number of sanitary improvements, waterclosets, the flushing of sewers, and things of that sort?—I daresay that is so. No doubt the use of waterclosets must have created a larger demand for water.

3945. What made you assume that you could go back to that 20 gallons the quantity having risen to 30?—I take the case of towns which are almost entirely provided with waterclosets, such as Nottingham and Norwich. I do not know of any places so well regulated, they are both under local governments, and in both those cases the use of waterclosets is pretty general, and in those places with a constant supply well looked after, the proportion does not ex-

ceed 19 gallons per head, that is the basis of my conclusions upon that point. Then I have founded another conclusion. We have made some very careful inquiries upon the proportions of water used in the better classes of houses as well as in the houses of the poorer classes. In fact it was an inquiry instituted by Mr. Simon and Mr. Haywood, the engineer to the Commissioners of Sewers, and this is the result of their inquiries which helps me in my conclusion upon that point. In first-class houses with from 12 to 20 rooms, with good cisterns and baths, and water supply, and waterclosets, and everything, they take upon the average 12·87 gallons per head. In second class houses, belonging to the better class, but still with good cisternage and waterclosets they take 7·41 gallons per head. Then we come to the poor with their bad receptacles, and they take about three gallons per head. Model lodging-houses come next, where every appliance is used, and where the water is not stinted, and in those cases it is exactly 6½ gallons per head for domestic purposes. Then as to our workhouses, in the Holborn Union, which is more liberally supplied with water than the other workhouses in London, five gallons per head is the quantity, in St. Martin's workhouse, 3·68 gallons per head, and in the Clerkenwell workhouse 3·1 gallons per head. We did upon that recommend that in the city of London 24 gallons should be supplied to every room upon the supposition of four people in a room, which is six gallons per head. Lately I thought it right to advance it to 30 gallons a room. I believe that engineers even in large manufacturing towns consider that scarcely ever does one half of the water go for manufacturing purposes. Therefore taking all those facts together I think that 18 gallons per head seems to indicate a very good supply for all purposes.

Dr. H. Letheby.
29 May 1867.

3946. At the present moment of those 30 gallons the greater part must be wasted?—It is so, there is no doubt about it. I suppose there is hardly a cistern to be found in the metropolis that has not its ball-tap out of order, with waste water running down almost all the time the water is on.

The witness withdrew.

James Muir, Esq., examined.

J. Muir, Esq.

3947. (*Chairman.*) You are engineer I believe to the New River Water Company?—I am.

3948. And have been so for some years?—I have been Engineer-in-chief to the company for more than seven years, and have been connected with them for a much longer period.

3949. You are therefore necessarily acquainted with the arrangements for the conveyance and distribution of the water of that company?—I am.

3950. Have you added at all to your capacity to supply of late years?—We have, and are still adding.

3951. Will you state what are your sources of supply, and how you have added to them, and what you propose to do in increasing that supply?—The sources of supply were originally the Chadwell and the Amwell springs. These were brought to London 250 years ago by Sir Hugh Myddelton. They were soon found not adequate, and a supplemental supply was obtained from the river Lea at a point between Hertford and Ware. The exact date of that I cannot tell, but it is supposed to have been not very long after the original bringing of the water to London by the New River. The point at which the company then drew water was between Hertford and Ware, and at that point they still draw, having diverted from it all the sewage of Hertford.

3952. Can you state the quantity which you draw from the springs, and the quantity which you are taking from the Lea at that point?—I should state that the Amwell spring, (one of those originally brought by Sir Hugh Myddelton) some long time ago passed into the river Lea and ceased to flow into the New River, and that now we have flow only from the Chadwell spring and the supplemental supply from the Lea.

3953. How far are those two springs separate?—They are only about two miles apart.

3954. Has the quantity of water in the basin of the Lea been enlarged so as to lead you to suppose that that spring has been tapped?—I do not know how originally the Amwell spring poured itself into the New River channel. It is close to the New River channel now, and the water of that spring finds its way at a lower level than the New River channel into the Lea, and we make no use of it.

3955. Can you account for that?—No.

3956. That must necessarily arise from depression of the water, has it been from any fresh tax upon the water?—Not at all. It may have been that the Amwell spring broke for itself an outlet at a lower level and so reached the Lea, instead of entering the channel of the New River.

3957. Can you state the quantity that you are now taking from the Chadwell spring?—We reckon that the Chadwell spring has an average flow of 400 cubic feet per minute or 3,600,000 gallons per day. That is the daily average. Sometimes the flow is very much more.

3958. Is that the average for a year?—It is the daily quantity for an average of years because the average of last year was 500 cubic feet per minute or 4,500,000 gallons per day. I may state that by Act of Parliament we are entitled to take in priority 2,500 cubic feet per minute from the Lea, that is 22,500,000 gallons per day.

3959. That I understand is your statutory limit, which are you actually taking?—The whole of our supply during the past year, was on the average 22,898,769 gallons a day from all sources.

3960. I understand that your maximum supply from the Lea, that which you are entitled to take under that Act, is 22,500,000 gallons?—We are entitled to take that *in priority*, but I should explain that that same Act of Parliament, to which I have alluded, empowers the New River Company and the East London Company together to obtain an additional quantity, in fact all the water of the Lea except a certain navigation quantity.

3961. You have a first claim upon the river to the extent of 22,500,000 gallons; I want to know whether you are taking up to your maximum quantity your legal quantity?—We took last year from the Lea about 18,000,000 gallons per day, on the average.

3962. (*Sir B. Phillips.*) What other sources of supply have you?—I will mention the other sources. We have six deep wells in the chalk; we have also, by purchase from the Hampstead Waterworks Company, the springs at Highgate and Hampstead collected in ponds there, and used for street watering, by separate mains; we have also power to draw water between Blackfriars Bridge and Southwark Bridge from the Thames. This is a power which the company have not exercised for many years, but they have there the means of taking water; they have a large suction into the Thames, and at any time when required they could draw water there for sewer purposes and street purposes, distributing such water by separate mains, so that it should not mingle at all with the supply for domestic purposes.

3963. (*Chairman.*) Have you duplicate mains throughout your district?—In some parts of the district we have separate mains, but for the general distribution of that Thames water for street and sewer purposes new lines of mains would require to be laid down, and the company contemplate laying them when the necessity for so doing shall arise.

3964. (*Col. Harness.*) Have you separate mains for the Hampstead and Highgate water?—We have separate mains for that water.

3965. (*Chairman.*) You stated, did you not, that

J. Muir, Esq.
29 May 1867.

the whole quantity which you distributed during the past year was 22,898,769 gallons per day?—Yes.

3966. (*Sir B. Phillips.*) Of which you took, I think you said, 18,000,000 from the Lea?—Yes.

3967. Where did you get the balance from?—We obtained 4,500,000 gallons from the Chadwell spring, and the rest from those ponds which I have mentioned at Highgate and Hampstead.

3968. (*Mr. Prestwich.*) You also stated, did you not, that you got some from wells?—Last year we hardly worked the wells, they were not required; we had them as a stand-by.

3969. What is the maximum quantity that you have obtained at any period from those wells?—We are remarkably fortunate in our ground for sinking wells. At Amwell Hill the yield is about 2,400,000 gallons a day from one well, and at Amwell End, not very far distant, a second well will yield about 2,500,000 gallons a day.

3970. Have you any other source to be added to your present means of supply?—We have that to which I alluded, namely, the power of obtaining, *pari passu* with the East London Company, any quantity of water that may be found in the valley of the Lea beyond the 22,500,000, a certain amount only being reserved for navigation purposes.

3971. Are we to understand that you are tied up to 22,500,000?—No, I stated that we had the power to take that quantity *in priority*, and then any further quantity *pari passu* with the East London Company, a certain amount being reserved for navigation purposes, all this being arranged under the River Lea Act, 1855.

3972. What is the plus of 22,500,000 gallons divisible between yourselves and the East London Company?—That additional quantity could only be obtained by making store reservoirs in the valley of the Lea. We contemplate making such reservoirs when we are so near our present limit as to make it necessary: and from the river Lea I calculate that we could get by making those reservoirs an additional supply probably of 10,000,000 gallons per day for the New River Company.

3973. Where do you propose to store it?—The best point for the collection and storage of the surplus water of the Lea I think would be below Field's Weir.

3974. Where is that?—It is near Hoddesdon.

3975. How far from London?—About 15 miles.

3976. What would be the gathering ground there?—There are several sites which would be available for reservoirs on the left bank of the Lea at that point. Higher up, the water might also be gathered into reservoirs, but there the difficulty of a non-retentive soil would make it a very expensive thing to construct reservoirs, as the clay, which is so useful in making a reservoir, does not appear until you come down the valley to Hoddesdon.

3977. You do not intercept any tributary, but you fill your reservoirs, do you not, out of the Lea itself?—Yes, out of the main stream.

3978. Then it would be simply a matter of choice as to where you should place your storing reservoir?—Yes.

3979. (*Sir B. Phillips.*) What amount of water are you allowed under your Act to draw from the river Thames between Blackfriars and Southwark Bridges?—There is no limit. We have not used that source for many years, but it is one which may be used for street and sewer purposes to any extent.

3980. You say that in addition to the 22,500,000 gallons which you now draw from the river Lea you might by making reservoirs draw another 10,000,000?—Yes, speaking roughly. The necessity for calculating the thing in detail has not yet arisen, but I think, looking at the gaugings of the river Lea, which have been very carefully taken at Field's Weir, there would be by proper reservoirs that quantity to be had in addition to the quantity which we now have.

3981. Then I understand you to say that you have two wells at Amwell Hill from which you draw something like 5,000,000 gallons a day?—Yes, we have; and we have a well at Cheshunt, and we have a well also in London at the Hampstead Road, and we have one on Hampstead Heath. The two last-named have not been used for many years, simply because there has been no occasion for it.

3982. (*Chairman.*) Have you observed a depression in the water of that well?—I have observed a depression in the wells in town, but not in those of Hertfordshire.

3983. To what extent?—The depression probably during the last 20 years in the Hampstead Road well may be very nearly 20 feet, arising, I should suppose, from the greater number of wells now in London, and the greater draught therefore from the chalk reservoir below; but the depression has not been apparent at all in Hertfordshire. The level stands as high in the Hertfordshire wells as it did 12 or 13 years ago.

3984. (*Mr. Prestwich.*) Including the one at Cheshunt?—The one at Cheshunt I cannot speak so accurately about. I happen to have a note of gauging by my predecessor, Mr. Mylne, at Amwell Hill, and therefore I speak of it certainly as not having fallen off. I think there may be a slight falling off in the Cheshunt well as you come down the valley, and then in town there is the greater falling off that I spoke of.

3985. (*Chairman.*) You bring the water by an open cutting the whole way, do you not?—It is covered for a distance of perhaps two or three miles.

3986. From where?—Part of it is tunnelled at Wood Green, near London, and part of it (after the river enters London) is enclosed by a brick arch and by pipes.

3987. What is the sectional area of your culvert? It is an open channel for the greatest part of the way.

3988. What is the size where it is covered for three miles?—The diameter of the tunnel, I think, is something like 14 feet.

3989. The rest of the cutting is open cutting?—Yes.

3990. Have you experienced any inconvenience from the frost or snow in the winter?—It requires labour in severe frost to keep the river clear by breaking the ice at the edges.

3991. I suppose it is necessary to release the ice from its hold at the side in order that a proper quantity may be supplied?—It is.

3992. But have you found any difficulty beyond the amount of labour necessary for breaking the ice on either side?—Many years ago I have heard that in very severe frost the river through frozen ice and snow was choked, so that for some time the supply was interrupted.

3993. For how long do you remember?—I do not remember, it was before my experience.

3994. Have you during the time that you have been engineer to the company observed any inconvenience arising to the water supply from a fall of snow?—There has been no interruption of the supply at all, but it has required a considerable amount of labour to break the ice at the edges as I have described, and to pull out at the gratings in the course of the river the lumps of ice which float down; men are kept night and day pulling the ice out to prevent its accumulation.

3995. Does not that entail considerable cost on the company?—In severe frost it does.

3996. Can you state what has been the cost of that operation?—I cannot exactly.

3997. How many men for example are necessary?—According to the severity of the weather the men are taken on, and I should think that a severe frost would cost us something like 500*l.* or 700*l.* for labour only.

3998. After the ice has been broken have you experienced no other inconvenience?—We have not.

3999. (*Sir B. Phillips.*) Supposing it were necessary to increase the supply to London, have you considered what quantity of water you could deliver from your present available sources?—The whole

quantity which we have the power of delivering now is more than 35,000,000 gallons per day.

4000. How much could you increase that from sources that you know of?—I hope by a new well now being sunk in the chalk at Wormley to obtain 2,500,000 gallons extra. By mains driven from the Thames in the way already described, I could find the means of disposing of another 2,500,000, and by making reservoirs in the Lea I could store a daily quantity of 10,000,000 gallons, and I think you will find the total to be 50,000,000 gallons a day.

4001. (*Mr. Harrison.*) Practically you could fully double your present quantity?—Yes, that would be more than double the average supply of last year which was under 23,000,000 gallons.

4002. (*Mr. Prestwich.*) What distance apart are those two wells in the neighbourhood of Ware from which you draw supplies?—They are not more than a mile apart.

4003. Have you pumped them both at the same time?—They have been pumped both at the same time without any effect being produced by the one upon the other.

4004. And did the pumping produce any effect upon the springs?—None whatever.

4005. (*Mr. Harrison.*) You have I suppose your reservoir in the chalk behind you?—Yes, we bore into the chalk at once, and the hills rise immediately at the back of the wells and supply them directly.

4006. Have you any driftways into the chalk at the bottom of your wells?—Not in all those wells; in the wells at Amwell Hill and the Hampstead Road which I mentioned we have.

4007. (*Mr. Prestwich.*) What is the depth of those two wells?—The depth of the well and bore together at Amwell End is about 390 feet, the Amwell Hill well 160 feet, the Cheshunt well 172 feet, the Hampstead Heath well 458 feet, and the Hampstead Road, well 237 feet.

4008. Have you tried the effect of sinking anywhere else besides those two points near Ware; for instance, have you tried nearer to Hertford?—By boring I have in several places.

4009. What has been the results of those trials?—Water was obtained in each case with great facility. I find that I have omitted to name, among the company's six existing wells, a new well at Hoddesdon in Hertfordshire.

4010. (*Sir B. Phillips.*) In these 50,000,000 gallons per diem, do you take into consideration any quantity that you might draw from the Thames?—Yes, I have put 2,500,000 for that, as I could find customers for it to that extent; but if the demand for such water increased we have the means always of meeting it from the Thames to a much greater extent than 2,500,000 gallons per day.

4011. Irrespective of that you are merely speaking I apprehend of the quantity which your consumers would like of you?—Yes.

4012. (*Mr. Harrison.*) The Thames water I presume would be merely applicable for street purposes?—Merely for street purposes, and similar uses. Therefore although we could take water to an unlimited extent from the Thames, I have only put down an amount that I can now find a use for.

4013. (*Chairman.*) I understand that you merely hold the Thames as an auxiliary aid in the event of a great pressure upon your ordinary supply for street purposes, the Thames water would answer your purpose?—Exactly so—for the streets, for fires, and for the sewers.

4014. (*Sir B. Phillips.*) What amount of capital have you in your company?—The company's capital now is 3,019,958*l.*, that is the amount which they have power to raise. The amount expended at the end of last year was 2,528,667*l.* 17*s.* 9*d.*

4015. (*Chairman.*) Is that the paid up capital or the nominal capital?—The capital of the company was settled in this way. During the inquiry of 1852 it was fixed by Parliament on a valuation of the company's works at 1,519,958*l.* Subsequently the company obtained powers by Acts in the years 1852, 1854, and 1857 to raise an additional 1,000,000*l.*, and last year they obtained power to raise 500,000*l.* more.

4016. That was for structural works, I presume?—Yes, for works.

4017. (*Sir B. Phillips.*) Is that capital raised by additional shares or by debentures?—The 1,000,000*l.* authorised under the Acts of 1852, 1854, and 1857 is borrowed money, the rest is in shares.

4018. (*Mr. Harrison.*) Would the present conduit be of sufficient capacity to carry that additional quantity of water to London which you calculate upon?—If not now of that capacity it can be made of that capacity with great ease. It varies in its sectional area. It was calculated, at the time when the company obtained power to improve their works in 1852, that the then proposed improvements would make it capable of carrying 50,000,000 gallons, and those improvements I believe were fully carried out, therefore I may say that even now the river is capable of carrying nearly double what it carries at present. The fall is such that by the slightest enlargement at those places where we have drops in the river that quantity could be easily brought on.

4019. Would the East London Company also be able to obtain a larger quantity for the supply of London from reservoirs in the upper sources of the Lea?—The reservoirs in the upper sources of the Lea would not yield water enough for both companies.

4020. Therefore if you were to take this additional quantity which you have mentioned, you would be taking all the surplus water of the Lea?—No, the 10,000,000 gallons I now calculate on is only about half the surplus.

4021. Would the East London Company be able to take that additional amount?—If they also made store reservoirs at about the same place below Field's Weir, which I have indicated for our use, they might obtain 10,000,000 gallons also.

4022. Have you tested the degree of hardness of the waters which come from the chalk wells?—Yes, we have had analyses made. When first brought up, the well water is somewhat harder than the water of the Lea, but it rapidly softens by exposure, and after mixture with the river water in our channel, the hardness of the two together is less than the hardness of the Thames.

4023. Taking the water where you take it from the Lea, and taking it at the point of delivery at the lowest end of your conduit into your reservoir, have you analysed the waters taken from those two points of your system?—We have had it regularly analysed as delivered at our works in town. Two analyses are made every month; one of the water as delivered to the works, and one as delivered to the consumers from the mains.

4024. But I want to see what change takes place in the passage of your water over the 16 miles of open conduit through which it passes?—I have had such analyses made, but only a few, and they show comparatively little change except in a slight softening of the water and in a less amount of organic impurity at the London end than at the other end.

4025. (*Chairman.*) Is there any chalk deposited in your water?—None whatever.

4026. (*Mr. Harrison.*) Has your attention been at all directed to the question of the softening of water?—It has. The suggestion having been repeatedly made that chalk water, if softened, would be almost superior to any other waters, the only thing that has prevented the company from doing that is the difficulty of accomplishing it on a very large scale, and also the risk that we have apprehended of a deposit by the crystallization of lime in the pipes, and the pipes being thereby choked.

4027. You in that respect confirm Dr. Letheby's evidence that where Dr. Clark's process has been used there has been an immense deposit of lime in the pipes?—That has been said, but I have no experience of it myself, not having tried it.

4028. Have you formed an opinion in your own

J. Muir, Esq.

29 May 1867.

mind, assuming it to be a practical thing to do it economically, as to the necessity of softening the water by any such process?—I think, taking into account the fact that the temporary hardness of the New River water is so much greater than its permanent hardness, that the gain would not be very great; and from the difficulty of applying the process on a large scale, and to the large quantity of water used for sewer flushing and street watering, and other purposes, (where the softening process is really useless,) we have not much encouragement to go into the thing.

4029. You have not any doubt at all that by the system of reservoirs, and the other means of supply at your command, you could increase your daily quantity so as to make it 50,000,000 gallons a day, if there was a necessity for that quantity?—I think it might be so, and there are yet means, I believe, of adding to the company's supply by sinking wells; and not only so—when the limit to be obtained from well sinking has been reached, the New River Company would be quite ready to co-operate in developing more fully the great capacity of the London basin, of which the Lea is but a part, for a great deal is yet to be done in the way of obtaining water from the Thames valley.

4030. Your attention, of course, connected as you are with the water supply in London, has been directed to the Thames valley as separate from the Lea?—It has.

4031. Have you gone into that to such an extent as to justify you in giving this Commission an opinion as to the capacity of the Thames valley?—Only in this general way; knowing the area of the Thames basin, and the very small amount of the rainfall of that basin, which is now used for the supply of London, it is quite clear that there is an immense quantity of water in it yet for use.

4032. You have made observations, have you not, on the rainfall and evaporation on the Lea?—Yes.

4033. Will you give the Commission the result of those observations?—I believe the average rainfall of the Lea valley may be stated to be 25 inches per annum.

4034. How much of that would be available?—For the formation of streams in the valley—between five and six inches are available.

4035. (*Chairman.*) Is that the average over a series of years?—Yes. I have gaugings as far back as 1850.

4036. And that average is 25 inches?—It is rather more than 25 inches.

4037. And you are of opinion, that after making a deduction for evaporation and absorption, and every other source of abstraction, about five inches of that 25 finds its way into the river, or, in other words, is really available as a water supply?—It is so, and the fact is ascertained by the actual gaugings of the stream.

4038. It is the net result, in point of fact?—Yes, it is the net result. The absorbing character of the soil on which that rain falls, it being chalk, has the effect of taking so much into the great reservoir below that there is only five or six inches left for the formation of streams.

4039. Is that partly due to the absorbing power of the soil, and partly due to the Thames basin being taxed by artesian wells, depressing the water from time to time, and thus giving it greater power to absorb?—I think it will depend more upon the character of the surface on which the rain falls; the surface on which the rain falls in the upper part of the Lea is very largely a spongy and chalky surface.

4040. Supposing that the Thames basin itself is tapped now by those wells, at different points, it is perfectly clear that up to that point the absorbing power is mastered?—Yes.

4041. Is not the fact of that basin being lowered, and the water depressed in it, the cause of a large amount of abstraction of water which falls upon the surface?—I think if the chalk formation is more abundantly penetrated by wells, the effect would be to draw down the water lower in the chalk, so that the chalk would become more recipient of rain. It would take in more rain, and to that extent there might be effect on the quantity of water coming down the stream.

4042. That is to say, if the present tapping were stopped, and the water, instead of being depressed, were to rise up to the surface and discharge at several outlets, the absorbing power of that area would be lessened to that extent?—Less water would, probably, go down into the chalk, and more would flow off in floods.

4043. (*Mr. Harrison.*) What was the date at which the Amwell spring ceased to yield water?—I do not know; it was a very long while ago.

4044. Was it before any influence could have been brought to bear by the act of pumping from your wells?—Yes, many years before.

4045. Has the question of running driftways for some miles into the chalk, and bringing the water out by gravitation, ever presented itself to you?—If you mean running a driftway into the side of a hill where the hills rise to a great height above us, it has not. The means of sinking vertical shafts into the chalk have been so easy, and we have got by that process so abundant a supply, that none seemed better.

4046. You are obliged, are you not, to pump those wells?—Yes, we are.

4047. (*Chairman.*) Do you know whether the system of running driftways has been tried in any part of the basin, and what has been the result?—I do not.

4048. (*Mr. Prestwich.*) I think you stated that although it is possible that the well at Cheshunt might be affected by the pumping in London, yet still the wells in that valley are unaffected by any such cause?—They appear to be quite unaffected.

4049. (*Mr. Harrison.*) Do you find the level of the water in those wells vary much after continued dry seasons?—It does slightly vary with the seasons, a wet or a dry year will make a difference, but no very great difference, only a few inches.

4050. (*Mr. Prestwich.*) Within what distance from the surface does the water rise?—In the higher wells of Amwell End and Hoddesdon it comes within a few feet of the surface.

4051. Have you been pumping at the Hoddesdon well?—Only experimentally, we have had no occasion to use it as yet. We do not know what quantity we shall get, inasmuch as the bore at the bottom of the well is now being carried down, but we have from the experimental bore a considerable supply exceeding 2,000,000 gallons.

4052. Do all those wells draw the water from the chalk?—All directly from the chalk.

4053. Can you put in an analysis of any of the waters from those wells?—Yes, I will do so.

4054. (*Chairman.*) Has your attention being directed to the question of constant supply?—It has.

4055. Do you see any practical difficulties in the way?—In London there are no doubt great difficulties. In a town to be supplied for the first time I think everyone would admit the desirability of a constant supply, care being taken to have everything in reference to the fittings of the houses of a proper description, and means being taken to have such supervision as would keep everything in order. The difficulty in London will arise from the amount of change required to make *old* premises ready to receive the constant supply. The position of the New River Company has always been this, that if their consumers will only take the supply without waste there would be no objection to give it on the constant system, and the advantages of the constant system would be very great in the houses of the poor. I think that the one disadvantage of the intermittent system is its needing cisterns that are liable to become fouled: and in the houses of the poor it is a most difficult matter to have cisternage so placed as not to acquire some foulness by vitiated air or other contamination. The New River Company have repeatedly offered to furnish the houses of the poor with a constant supply if the landlords of such

property would only take water in some way that would insure the company against waste.

4056. (*Sir B. Phillips.*) Has application been made by some of your consumers to your company to supply them on Sundays?—Yes, and that application has in very many cases been granted.

4057. (*Mr. Harrison.*) What is the level of your reservoirs where you filter above ordnance datum?—They are about 86 feet above the Thames high water.

4058. Has your attention been directed to the consumption per head, and what you would consider, taking all things into account, to be the proper consumption?—It has, and I have made experiments upon a pretty extensive scale, for the purpose of ascertaining what would be a fair amount for various purposes in London. In houses of an average class, where means were taken to prevent waste, but where there was no stint (where there was a full allowance of water), the consumption has not exceeded seven gallons per head per day. In houses of a larger class the consumption is somewhat greater and in small houses somewhat less. But I have been in the habit of allowing 10 gallons per head per day as ample for ordinary domestic purposes.

4059. Including all other requirements, what do you put it at?—I have said that 20 gallons per day in a city like London, where manufactures are by no means many, would be a very good allowance.

4060. (*Chairman.*) Would that include manufacturing purposes, street purposes, the suppression of fires, and every other purpose?—For manufacturing purposes to the small extent found in London, for all fire purposes, and for all street and sewer purposes, as well as for every domestic use, 20 gallons per head per day would be sufficient.

4061. (*Sir B. Phillips.*) That is over the metropolitan area?—Yes.

4062. (*Chairman.*) That would be 60,000,000 gallons a day?—Yes.

4063. (*Mr. Harrison.*) Taking the present consumption to be 30 gallons per head per day, to what would you attribute the difference?—The difference is due entirely to waste.

4064. Do you think that means can be taken to prevent that waste?—I think a great deal more might be done than is done now for the prevention of waste. The companies, and the New River Company I may say especially, have attempted to check waste to some extent for the sake of the consumers, (for the waste of one set of consumers is very injurious to another, who may be upon a higher level,) and they have succeeded in some measure in reducing waste, without in the least degree stinting the proper supply of their tenants.

4065. But taking it as a practical question, do you believe that the present supply being 30 gallons, you can calculate that it could be reduced to 20 gallons?—I think it might. Were a constant supply introduced it would be necessary to have very strict supervision indeed, for the purpose of preventing waste, and if that strict supervision could be borne by the inhabitants and if the requisite power were granted to the companies or to local authorities to control the condition of things in houses, I think that the supply might be brought within more reasonable limits than it reaches to now.

4066. You have been examined upon that point before Mr. Ayrton's committee, have you not?—I have.

4067. Do you advocate the entire abolition of cisterns in the case of a constant supply?—Not at all, I think it would be a very inadvisable thing. I believe the whole question was gone into in the years 1851 and 1852 before Parliament, and the result come to then was that cisterns should in all cases be provided, and it is so arranged in the Metropolis Water Act of 1852. I think in all houses of a better description where there is a possibility of putting cisterns in proper places, cisterns should still be required and only in the houses of the very poor should cisterns be dispensed with, and water taken on the constant system through some waste preventing apparatus.

4068. (*Chairman.*) Although you would retain the cisterns, you would still have a constant pressure upon your mains?—There would still be a constant pressure upon the mains, and a constant pressure upon all mains would be decidedly an advantage, especially for fire purposes. When I speak of mains under a constant system I mean all the companies' pipes, because at present a portion only of the companies' pipes are always charged, and they alone are called "mains" by the companies. Other portions (the branch pipes of the companies) are intermittently charged and they are called "services." The effect of giving a constant supply to all those pipes would be to enable a direct fire supply by a hydrant to be taken from the "services" as well as from the "mains." But I still say that the difficulty arising out of the enormous expense which would be thrown upon the owners of house property in making houses fit to receive a constant supply would be so great in London, that a general adoption of the constant system here appears to be almost impracticable.

4069. (*Mr. Harrison.*) Of what could that expense chiefly consist?—It would chiefly consist in laying down new lead pipes for those at present in use. Many of the lead pipes in London are very old and very feeble, and the least increase of pressure would cause them to give way. The fittings also are of a very imperfect kind. Under the intermittent system those pipes are all saved from the night pressure. The pressure of water at night when no one is drawing from the mains, is very much greater than the pressure during the day, and as houses are now served, those lead pipes are only subjected to pressure during the day and are saved therefore from the higher pressure of the night. Under the constant system they would come under that higher pressure, and in the great majority of cases they would give way.

4070. If your view is correct that you could reduce the consumption per head from 30 gallons to 20, there would be a saving in that case of water to the water companies of 33 per cent.?—There would.

3071. Would not that saving of 33 per cent in the quantity of water that they supply, enable the water companies to bear such an expense as would be involved in the alteration of the services to the houses?—I think not.

4072. (*Mr. Prestwich.*) Would the system of constant supply entail a large expense upon the water companies?—To a certain extent. The New River Company has already incurred a very large expenditure in preparations for the constant supply. It was arranged by the Metropolis Water Act of 1852 that the companies should prepare themselves after an interval to give a constant supply, and that if four-fifths of the inhabitants on any district main should come to a company asking for a constant supply, and put themselves in order to receive it, the company should be bound to give it. Under those Acts of 1852, 1854, and 1857, which I mentioned, the New River Company laid out something like 800,000*l.* in the general improvement of their supply, providing filtering beds, laying down large new leading mains, and constructing high service covered reservoirs, all of which were in preparation for this improved constant supply. As yet no applications have been made for a constant supply, and a constant supply therefore has not as a general rule been given, though there are exceptional cases in the New River district where the supply is constantly on.

4073. (*Col. Harness.*) What do you understand by the householder putting himself in a position to receive the constant supply?—The lead pipes must be made of sufficient strength by him, that is, for his own sake. He must take the water for the watercloset use out of a service cistern with a double valve, so that there shall not be waste in the watercloset (one valve always being shut while the other is open). While the water is being drawn into the closet the water is prevented from coming from the main into the cistern, and so waste is effectually prevented. He would require to have all his ballcocks and taps of the best description, and one thing which has been found almost always necessary in every house in which a constant supply

J. Muir, Esq.

29 May 1867.

has been given is to forbid overflow or waste-pipes from cisterns, so that consumers shall have a very good reason for taking care that ball-cocks are always in perfect working order.

4074. (*Mr. Harrison.*) What do you calculate the average to be per house for making those necessary alterations?—I have calculated that on the average, to do the thing properly, it would take something like 8*l.* per house all over London in order to put the houses in a proper condition for receiving the constant supply.

4075. (*Col. Harness.*) That 8*l.* would lie between two extremes; what would it be for a small house, and what for a large one?—I think for a small house it might take 4*l.* or 5*l.*, and in larger houses a very great deal more.

4076. Would you say 12*l.* or 14*l.*?—Yes. Where the pipes are built into the walls and have to be cut out and the decorations made good, the expense might be 20*l.* and upwards. In some cases it has been said and often felt, I believe, that the companies obstinately stand in the way of a constant supply. I do not think that at all to be the fact. If a constant supply could only be carried out here in London as it is said to have been carried out in some other places, with a great reduction in the quantity of water consumed, the companies should hail it; it would be a great matter to them to be able to dispense with the services of many turncocks, and save water at the same time.

4077. Is your annual expenditure large in proportion to the quantity of water delivered?—The pumping and filtering expenses are considerable, but they are small, compared with the general expenses.

Analysis of Water from Deep Chalk Well, Amwell, Herts.

	Grains per Gallon.
Carbonate of lime and magnesia	15·51
Sulphate of lime	2·51
Alkaline chloride	1·12
Alkaline nitrate	0·24
Silica and alumina	0·67
Organic matter	0·52
Volatile matters and loss	0·98
Total	21·55

The witness withdrew.

Adjourned to to-morrow at 11 o'clock.

Thursday, 30th May 1867.

Present:

Sir John Thwaites in the Chair.

Sir Benjamin Phillips.	Thomas Elliot Harrison, Esq.
Colonel Harness.	Joseph Prestwich, Esq.

H. H. Fulton, Esq.

30 May 1867.

Hamilton Henry Fulton, Esq., further examined.

4078. (*Chairman.*) I think in your evidence on the former occasion you had arrived at the point when you were about to describe the estimate for your plan?—Perhaps before entering upon that you would allow me to state that I have the returns here of the rainfall to which I referred, and which were taken at Cefnfaes, near Rhayader, and a copy kindly furnished me by the observer. I had not the returns with me on my last examination, but now I have them up to the end of the year 1866. From 1858 to 1866. As I stated, the position of this rain gauge is nearly the lowest point in the watershed No. 1, to which I referred, and consequently I consider that the results are very much lower than would be obtained in the higher portions of the watershed. For those nine years I find that the average is 45·13 inches.

4079. Have you any other gauging?—This is the only gauging that I have in that district. There are others in the neighbouring valleys but not in the immediate district.

4080. Can you tell the Commission the smallest amount of rainfall which occurred between 1858 and 1866?—The smallest that has been observed was in 1858, which I believe generally throughout the country was a very dry year; in that year the amount was 35·11 inches.

4081. What is the highest year?—The highest year is 1860, which gives 59·52 inches.

4082. Have you any other information to give us with respect to the rainfall?—There is one point which I should be very glad to draw particular attention to, which is this, that I have taken the net available amount of rainfall in this district at 30 inches, which I stated before, but which I wish to draw particular attention to because I understand that Mr. Bateman in his Severn plan takes it at 36 inches.

4083. Do you think that the rainfall in your district would be equal to that in Mr. Bateman's district?—Yes. I cannot conceive that there should be any difference.

4084. You are just on the other side of the ridge, are you not?—Yes, just on the other side of the ridge.

4085. How do you arrive at the 30 inches net rainfall which you say would be available for the water supply?—It is on the assumption that the minimum rainfall of the district averages 60 inches, but then in order to give a considerable margin of safety, from that I deduct 30 inches.

4086. But the only evidence you have is this gauge which has been accurately kept you say from 1858 to 1866, and that gives an average of 45 inches, and that gauge was kept at the lowest point?—Yes; and therefore I assume that in the higher portions the rainfall must be very much larger than it is at this particular point, and also as the circumstances of the locality are very similar to the lake district, I consider I am safe in assuming that the rainfall is something similar to the rainfall of the lake district, and I think that the observations which I have just been referring to tend to show that that is so.

4087. Assuming that it would be equal to that of the lake district or that the 45 inches is a fair test of the yielding power of that area, how do you ascertain the abstraction by evaporation and absorption; what means have you of determining that?—It is only from observations which have been made in other instances. For instance, Mr. Bateman, who has had as much experience in that kind of thing as anybody, puts it, I think, from 9 to 16 inches.

4088. That is dependent, is it not, upon the nature of the surface, whether it is of an absorbing character or not?—Yes; but the surface of the whole of this district is of the Silurian formation, and is composed entirely of clay and rock, and the consequence is, I consider, that there must be a less amount of absorption in this district than there would be in almost any other.

4089. From its mountainous character you think that the water would rapidly run off?—Yes, I think so, because the hill sides are very steep as well as the material being very non-absorbent.

4090. (*Mr. Prestwich.*) I suppose there are very

few springs in the district?—I do not think there are very many springs in the district. By far the principal portion of the water would be derived from the rainfall and not from the springs.

4091. Therefore, beyond your rainfall you would have nothing to fall back upon?—There are springs; when I say there are no springs, I mean that comparatively speaking, compared with the total quantity of water derived from the rainfall, the quantity derived from springs would be small.

4092. The rocks being hard and non-absorbent they would not store water?—That does not quite follow, because of course the springs might come from the fissures of the rocks.

4093. (*Chairman.*) Will you now give in the detail of your estimate?—I have made an estimate for the first 130,000,000 gallons to be derived from the No. 1 watershed. The aqueduct I put down at 3,778,114*l.*

4094. Have you made any sections to enable you to make that detailed estimate?—None except those to which I referred in my evidence. I have sections of the sites of the proposed reservoirs.

4095. Then you have assumed the quantities in the other case?—I have got them out as well as I could from the rough section which I exhibited to the Commission on my former examination. Of course, as I said before, this can only be taken as a roughly approximate estimate.

4096. (*Mr. Harrison.*) As an engineer you would not absolutely pledge your reputation to this being an estimate for which you would complete those works?—I think I might do so safely.

4097. (*Chairman.*) Have you allowed yourself sufficient margin to carry you over any contingencies that might arise?—Yes, I think so.

4098. I suppose you have had regard to the Ordnance map?—Yes; I have availed myself of all the information I could get in every shape and way, both with reference to the Ordnance maps, the Ordnance levels, the levels of railways and canals, and other levels.

4099. (*Mr. Harrison.*) Does your estimate give any details?—No; if you will allow me I will hand in my estimate.

The witness delivered in the following estimate:

Estimate of first 130 million gallons.

	£	s.	d.
Aqueduct - - - -	3,778,314	0	0
Reservoirs, &c., in No. 1 watershed -	400,000	0	0
Service reservoirs, pipes from service reservoirs to London, and alterations of existing works - - -	970,000	0	0
	£5,148,314	0	0
Contingencies 10 per cent. -	514,831	0	0
	£5,663,145	0	0
Land and compensation -	470,000	0	0
	£6,133,145	0	0
General expenses, interest during construction, &c. - - -	866,855	0	0
Total - - -	£7,000,000	0	0

Estimate of additional 100 million gallons.

	£	s.	d.
Additional inverted syphons - -	520,000	0	0
Reservoirs, &c., in No. 2 watershed -	330,000	0	0
Service reservoirs, additional piping to London, &c. - - - -	640,000	0	0
	£1,490,500	0	0
Contingencies 10 per cent. -	149,050	0	0
	£1,639,550	0	0
Land and compensation -	180,000	0	0
	£1,819,550	0	0
General expenses, interest during construction, &c. - - -	180,450	0	0
	£2,000,000	0	0

4100. (*Chairman.*) I see you give two estimates, the first showing what would be required for the collecting and storing and conveying of 130,000,000 gallons per diem?—Yes.

4101. Then you add a supplementary estimate for an additional 100,000,000 gallons per diem?—Yes, but I did not intend to have entered upon that, it is not got out with the same care with which the first estimate of 130,000,000 gallons has been got out.

4102. Then your estimate as a whole for 230,000,000 gallons would be 9,000,000*l.* sterling?—Yes; that is considering in the first instance that the aqueduct is taken as of sufficient capacity to convey the 230,000,000 gallons with the exception of the syphons and the reservoirs.

4103. Did you state in your last evidence the point where you propose to form your reservoir near to the metropolis?—I did state that it was to be near Totteridge. There is a very desirable site there I consider for a reservoir comprising about 400 acres of ground, and which I described as being about eight miles from the Marble Arch.

4104. What is the height of the reservoir above datum?—The height of the water level will be about 276 feet above Ordnance datum.

4105. Is it a clay soil there, or would you have to puddle?—It is all clay.

4106. What is the estimate per acre for the land?—I estimate it at 400*l.* an acre at that distance from London.

4107. (*Mr. Prestwich.*) Is it all grass land?—Yes, and there are no houses upon it. I do not think there have been any new houses built near there for years.

4108. When you finish your works at Totteridge have you in your scheme provided any mains or arrangements for the purpose of bringing the water to London or for distributing it when it is brought?—I should connect it of course with the different companies' systems of pipeage which now exist.

4109. But you would not sacrifice your 276 feet by bringing your water down to a lower point, would you; you would not bring it to Thames Ditton for example?—It would be so arranged that wherever a connexion took place with the present system of pipeage the pressure of the water would be calculated to the extreme height of the district; except the amount by which it might be reduced by friction, the pressure would be the same at similar levels throughout the whole present system of pipeage.

4110. But the companies have to pump, as you are aware, from the Thames valley; and if you bring your water and discharge it into their reservoirs it is quite clear you lose your pressure?—But I should not think of bringing the water into their reservoirs. As I said before, the existing pipeage would be connected with the service reservoir, and the pressure at similar levels would be universally the same throughout, except the amount to which it might be reduced by friction or by partially shutting off the water in certain districts so as to prevent danger from excessive pressure.

4111. My point is whether you intend to bring your water by means of iron pipes and utilize your head of 276 feet, and attach your pipes to the pipes of the companies, and thus sustain your pressure, or whether you propose to bring it into the reservoirs and therefore lose your pressure?—No, not the latter, certainly; all present pumping below the level of the proposed service reservoirs would be entirely done away with, and I should thereby secure a very large saving of expense.

4112. How do you connect it with the service of the present companies?—There would be mains which would be taken from the service reservoir to the different existing systems of pipeage.

4113. Then you would distribute it to certain points?—Yes.

4114. Have you directed your attention to the necessary arrangements to be made by the existing companies?—I have considered the thing generally, but not of course in detail. I may just remark, and

H. H. Fulton, Esq.

30 May 1867.

which would exemplify the thing to a considerable extent, that the Grand Junction Company propose to pump their water up to an elevation of 265 feet at Shoot-up-Hill, which is only 11 feet lower than the point at which the level of the water at my service reservoir would be, so that it would be simply to connect my service reservoir with the Grand Junction mains, and the company would then be placed by gravitation in the same position as if their proposal of pumping to the great elevation of 265 feet were carried out.

4115. But how do you propose to deal with the existing water companies with regard to their capital?—That I have not gone into at all.

4116. When we find you at Totteridge with the water from your Welch district you are there a wholesale dealer; you have no connexion whatever, have you, with the existing water companies?—There would be a physical connexion as I before described; but as a matter of policy I have not gone into it at all; I have simply looked at the thing in an engineering point of view.

4117. Does no scheme occur to your mind with respect to that?—None that I should like to enter upon.

4118. (*Mr. Harrison.*) In your estimate, taking the third item you say, "service reservoirs, piping from "service reservoirs to London, and alterations of ex-"isting works, 970,000*l.*;" what are the particular alterations there you referred to?—It would be necessary, of course, in order to distribute the pressure in an economical way to make certain alterations in the different existing systems of pipeage.

4119. Is that based upon any detailed calculation of what the expense would be?—As detailed a calculation as I could make without having proper surveys.

4120. It does not go into the question of the necessary alterations of houses in order to take the constant supply?—No, it does not include that at all. So far as the present system of house supply is concerned I have not attempted to deal with it; as to the conversion of the present system into a system of constant supply, I have not included anything in my estimate for that. By the arrangements which I propose the supply could either be made upon the constant system or intermittent as at present; what I mean to say is, that there is nothing connected with this plan which would prevent the adoption of the constant system, if that were thought desirable.

4121. (*Col. Harness.*) But in taking that 970,000*l.* have you entered into detail so far as to consider how you would communicate with each company?—In a very general way; I could not deal with that question in detail without having a great deal of information which I am not at present possessed of.

4122. But as far as you could you dealt with each company's works separately?—Yes.

4123. And, therefore, you selected a point of junction with each company's works?—Yes; there are several ways by which it could be done, which I think would be of equal cost, but which of those ways would be the best I have not yet decided.

4124. (*Mr. Prestwich.*) What will be the width of the line of land that you will have to purchase for your aqueduct?—That would depend entirely upon the depth of the cutting, the width of the embankment, and whether the aqueduct was in tunnel or not; wherever the aqueduct is in tunnel, the usual way is merely to purchase an easement through the lands through which the tunnel goes.

4125. You have given us the length of open aqueduct; what upon the average would be the width of land for your aqueduct?—On the average, when it was covered or in tunnel, it would be about 40 feet I should think.

4126. And in aqueduct would it be the same?—No; I have not gone into it in that way, I am only giving it roughly.

4127. (*Mr. Harrison.*) Are there not some lead mines which you will have to deal with in your district?—There are only two, I think; there is one about four miles below Plynlimmon on the river Wye.

4128. (*Chairman.*) What is the extent of that mine?—It is not a very extensive mine, and I understand that within the last few months it has been given up on account of its not being remunerative.

4129. Do not the washings from that mine find their way into the river Wye?—Yes, as I stated in my evidence on the last occasion, but the washings from the works which are commenced there will be diverted.

4130. How would you deal with it?—I should simply divert it along the side of the hills and prevent its running into the reservoirs.

4131. You must have a culvert running parallel with the river all the way; where would you propose to take it?—Wherever the point of abstraction was I should take it below that point in a pipe or open drain.

4132. Have you considered the cost of that?—It would be a very trifling affair.

4133. Are there no means of getting rid of it by settling tanks?—I have not calculated upon that. I think, physically, it could be got rid of in the way that I speak of.

4134. (*Col. Harness.*) What would be the quantity of water from those washings which you would have to provide for?—It would be very small. I could not tell what the quantity would be; a comparatively small drain would take it away.

4135. (*Chairman.*) Where is the other mine?—There is one in the watershed No. 1, at Nantycar in the Claerwen valley.

4136. What is the extent of the working there?—I do not think they have been working there very long; the workings are very small.

4137. Do you know how many men are employed in that mine?—I think there are about 15 men, women, and children employed.

4138. Do you propose to deal with this mine in the same way as the other by diverting its water and carrying it to a point where it would not contaminate the general stream?—Yes.

4139. (*Mr. Harrison.*) What do the people at the point where you discharge all that water say to it?—If they were injured in any way they would of course be entitled to compensation.

4140. Do not you think that it would be a matter of absolute necessity to get rid of it by means of reservoirs, that is to say, running it into reservoirs and allowing it to settle instead of carrying it and discharging it into the river below?—I have no doubt that that might be done, but I cannot say that I have gone into that question, because I thought it could be dealt with in the way I propose. I have only looked at it as an engineer; of course the water might be diverted.

4141. (*Chairman.*) In point of fact it is only a question of expense?—Precisely so.

4142. (*Mr. Harrison.*) Could you give us the prices at which you have estimated your work?—The earthwork I have taken at 1*s.* 6*d.* a yard; the excavation in tunnel at 5*s.*; the lining for the open aqueduct I have taken at 1*l.* per foot forward; the brickwork I have taken at 22*s.*, and the concrete at 7*s.* 6*d.*

4143. What concrete would you use, concrete in cement or what?—Concrete in lias lime.

4144. (*Chairman.*) Do you think that 5*s.* per cubic yard is sufficient to carry you through your tunnel?—I think so as an average price. The brickwork in the tunnel I have taken at 30*s.*; the concrete in the tunnel I have taken at 10*s.*; and the bridges, culverts, and fencing I have taken at 2,400*l.* a mile for 161 miles.

4145. Do you mean bridges to connect the lands severed by your cutting?—Yes.

4146. (*Mr. Harrison.*) What have you allowed for the pipes where you cross valleys?—The pipes I have taken at 7*l.* 10*s.* a ton.

4147. Is that for the pipes fixed in their places?—

Yes, fixed in their places, but not including the cost of excavation.

4148. Do you propose to have them submitted to any process for protecting them?—No.

4149. Would you lay them down merely as they came from the foundry?—Quite so.

4150. Does that embrace the whole of the large items?—Yes, those are the whole.

4151. (*Chairman.*) Are you of opinion that the boiling of the pipes and covering them with a solution is a failure?—Really that is a very abstruse chemical question which I am not prepared to enter upon. I have heard discussions amongst chemists of great eminence who seemed totally to disagree with regard to the different mixtures which are in use.

4152. That mixture does not prevent the oxidization of the metal?—I do not presume to say that, because I really do not know.

4153. Is your doubt with regard to their endurance or what?—I am only guided in my opinion by the result of experience in other cases where pipes have been in use, and they have not been found to corrode to any injurious extent.

4154. Does that apply to pipes not covered or coated?—The pipes in London are all laid down without undergoing that process. The West Middlesex Company are at this time laying down pipes of large size which are not coated in any way.

4155. Yours would be very soft water; would that have any effect upon the pipes?—It might do so, but that is also a chemical question upon which you might get much better information from other parties.

4156. At all events it forms no item of your estimate?—No, it does not. There are one or two things which I should like to refer to, which are in the heads of evidence with regard to soft water. I think that one of the strongest instances that I know of where soft water is sought after and appreciated to a great extent by the poor people is a case in the neighbourhood of London. At Hammersmith and the adjacent district there are three or four artesian wells from which they get water, and the proprietors of these wells sell the water, and it is taken about in butts and sold to the poor people at 1*s.* 6*d.* or 2*s.* per butt, or in small quantities a halfpenny a pailful. I have made inquiries about this and I find that they take this water because it is soft they say, and although the company's water is laid on to their premises yet they would rather pay a halfpenny a pailful for this water to make tea and for washing purposes than use the company's water.

4157. Do you know whether the water is soft?—So I am told. I have used some of it for washing and found it certainly very soft, but I have had no chemical analysis made of the water.

4158. May not the poor people to whom you refer buy it under the impression that it is spring water?—No; they buy it on account of its softness. There are a great number of laundresses in that district, and they use it for washing purposes. I think that is the best practical example of the appreciation of soft water.

4159. (*Mr. Prestwich.*) Is the water obtained from beds under the London clay or from the chalk?—The depth of the water in the wells is some 315 feet. I do not know whether they reach the chalk, but I should think it probable that they would just reach the chalk.

4160. Then those waters would be soft, not from the absence of mineral matter but from their containing salts of soda, like the water in the artesian well at Charing Cross?—I do not know how that might be, you are better able to give an opinion upon that point than I am.

4161. It would not be analogous to the water from Wales, would it?—I cannot tell, of course, the origin of the softness, but I know that the water is soft to the feeling. I only mention this to show that those poor people do greatly appreciate the value of soft water, and will use it if they can possibly get it, even by paying very enormously for it, for I consider 2*s.* per butt is an enormous sum for them to pay, it being about 26 times the price of the water supplied by the water company.

4162. But those waters from the presence of salts of soda may have a detergent effect apart from the purity of the water such as that which you would propose to introduce, it may have a natural action?—Yes; but what I wish to show is that those people consider this water soft, and no doubt it is soft for washing purposes, and they appreciate the advantages of that to such an extent that they pay this large sum for it. I have not had the water analysed, and am not at all acquainted with the ingredients which it contains.

4163. (*Chairman.*) Except the fact that you know it to be soft?—I know it to be soft from the feeling. I have not tested it in any other way.

4164. (*Mr. Harrison.*) What Mr. Prestwich points to is very obvious, that they attach great value to this water for a special purpose, that is, for the purpose of washing?—Yes, and for making tea.

4165. And Mr. Prestwich explains what the composition of that water is which makes it peculiarly applicable for that special object?—I have no doubt Mr. Prestwich is perfectly right.

4166. (*Mr. Prestwich.*) All these waters are very uniform in their composition, and it is very probable that the presence of salts of soda may produce a direct effect?—No doubt, but I should like to draw attention to one point which is very often referred to by the advocates of the present supply, which is this: You constantly hear it said that the water is softened by boiling; in almost every chemical analysis which has been made of the Thames water it has been stated that the water would be reduced to three or four degrees of hardness by boiling; but the real meaning of that is this: as I have said before I am no chemist, but I conceive the water must be raised to the boiling point, then allowed to cool, and the carbonate of lime to precipitate before it is soft; then of course it might be used afterwards as soft water, but that would be a most expensive process for poor people to adopt in order to get soft water.

4167. (*Chairman.*) Your point is rather this, is it not? It is true you have water of, say, 14 degrees of hardness, but as so large a portion of that water is used for washing purposes after being boiled, the hardness in point of fact in practice is reduced to from three to five degrees of hardness?—If that were the case I cannot see why those people about Hammersmith who use water for washing purposes should prefer this water to which I have been referring to the water which they get from the water companies. As a rule I do not think that the company's water is raised to the boiling point for washing purposes. This soft artesian well water is sold by the butt, which contains about 110 gallons, at 1*s.* 6*d.* and 2*s.*, as I before stated, dependent upon the distance from which it is carted from the well.

4168. (*Mr. Prestwich.*) I would remind you that those waters are much more impure actually than the Thames water?—Yes, that may be so. The only reason I have for drawing attention to that water is to show that the people conceive this water to be soft, and no doubt they find it soft, and they find an economy in using this water both for making tea and for washing purposes, and I contend that if soft water could be brought to London people would very much prefer soft water to any other which could be supplied to them.

4169. (*Chairman.*) You mean for those purposes especially?—Or for any purpose; I may say that I should have made it a point to have had the River Wye waters and the waters about London analysed in order to have furnished information, as to their composition, but it was intimated to me that the Commission contemplated having all these waters analysed.

4170. (*Mr. Prestwich.*) I think you stated before that you had not had the waters of your district in Wales analysed?—No, for the reason I have mentioned. I should have had them analysed, and I was in communication with some of the most eminent chemists

H. H. Fulton, Esq.

30 May 1867.

with the view of having it done, but I was informed that the Commission would have them analysed.

4171. (*Chairman.*) We have had samples taken on Mr. Bateman's gathering ground. You do not apprehend, do you, that there would be any difference in the chemical properties of the waters on the one side of the hill and on the other?—It would be more satisfactory to me if the waters on both sides of the hill were analysed. It is an important point, and I should have been very glad to have given the information to the Commission if I had not thought that they would obtain it in some other way and from what they might consider a more reliable source. I may observe that I have taken up samples of the River Wye water, and have kept them in bottles since the 14th of September last, and the water appears to be entirely free from any smell or any trace of putrefaction. Perhaps I may be allowed to state that as regards the sparseness of its population the Wye Basin compares very favourably for water supply purposes with the other large river basins of England and Wales; thus while the Thames above Hampton contains a population of 224 to the square mile and the Severn above Tewkesbury 378, the Wye above Monmouth only contains 97 per square mile.

The witness withdrew.

T. Orton, Esq.

THOMAS ORTON, Esq., examined.

4172. (*Chairman*). You are medical officer to the Limehouse District Board of Works, I believe, and you have held that appointment for some time?—Yes, between seven and eight years.

4173. You were actively engaged in the discharge of your duties during the time of the recent outbreak of cholera in that district?—Yes.

4174. Will you state to the Commission your views as to the cause of the outbreak in that particular locality?—To do so it will be necessary to explain a little previous circumstances, and I will be as brief as I can in doing so; during the excessive high temperature in June and the commencement of July I was quite prepared, from experience, for an outbreak of fever.

4175. What were the premonitory symptoms that led you to that conclusion?—The excessive temperature and the strange dry atmosphere; I found that people generally complained of it. They complained, moreover, of peculiar sensations arising from this state of the atmosphere, such as a burning in the throat, and a disposition to sneeze without any cold, and symptoms of that character, which were unusual and which they had never before experienced. However, instead of fever, for which I was prepared, an outbreak of cholera occurred, and this circumstance led me to watch the disease more minutely in relation to its cause than I otherwise should have done; I found that the cholera had commenced in the fever districts, and more especially in those localities where I had always found fever, and amongst that class of people who are more particularly subject to fever; I was in doubt at first as to the cause of it. The Registrar-General had given out that the water was the origin of the cholera, and the impure water from the East London Waterworks at Old Ford more particularly.

4176. You first referred to the condition of the atmosphere producing great dryness upon the surface of the skin and creating a tendency to sneeze, or a kind of influenza sensation; can you at all account for that condition of the atmosphere locally?—It was generally regarded by the parties who had spoken of it to me as atmospheric; that there was something unusual in the atmosphere which had caused those unpleasant symptoms.

4177. Why should those terrible results follow in that limited area and not in other parts of the metropolis, if it were merely atmospheric, unless the cause of the condition were local?—I believe it was principally local.

4178. Arising from what cause, in your judgment?—There were a great number of sources of nuisance at the east end of London, more particularly about Bow Common and the river Lea at that time, which gave rise during that excessively hot weather to foul gases and noxious effluvia.

4179. Then in your opinion it was a combination of causes rather than any single cause?—Yes, owing to the foul gases and the fearful vapours which were carried by the north-east wind which prevailed for several days in the direction from this field of nuisances; I may say nuisances, because it was not only the river Lea at that time, but numerous factories all within the area to which I am now referring.

4180. (*Sir B. Phillips.*) Were those symptoms of which you speak limited to any particular class of people?—No, they were general.

4181. (*Chairman.*) Was it the water do you think that had any effect upon the constitution to produce those symptoms?—No, I have no reason to think anything of the kind.

4182. You are rather inclined to the view that it was atmospheric?—Yes, it was atmospheric at first.

4183. Produced by a variety of causes, including the drainage, and I suppose that that is a part where the main drainage is not completed?—Just so.

4184. Do you think that the water had anything to do with it?—I am very much disposed to question it. At first I was disposed to coincide with the Registrar-General, because I was utterly at a loss to account for it; but as time went on from day to day, watching it closely as I did, I came to the conclusion that the water had little or nothing to do with the matter.

4185. You have two distinct waters supplied there, have you not?—Yes.

4186. Will you describe those waters?—One is from the Old Ford reservoir, and the other is from a reservoir higher up.

4187. It is the Old Ford water, is it not, which is alleged to be so impure?—Yes.

4188. Have you carefully watched the area supplied by the Old Ford water as contrasted with the area supplied from the higher source?—Yes, I have.

4189. What has been the result of your observation?—I found that in the area supplied by the Old Ford water the disease was very remarkably more prominent.

4190. How do you account for that fact?—I account for it in this way, that the Old Ford water supplies those districts more immediately coming within the operation of those nuisances through the north-east wind.

4191. (*Sir B. Phillips.*) You attribute it rather to the district to which the water is supplied than to the water itself?—I do not altogether say that the water has nothing to do with it; I would say it has very little to do with it. I think that the nuisances on Bow Common and the river Lea at that time had a very great deal to do with it.

4192. You have seen the report of the Registrar-General, have you not?—Yes.

4193. You saw that he spoke very strongly as to the effects of the water?—Yes.

4194. (*Chairman.*) You made a report to your board, did you not, on the subject of the cholera?—Yes.

4195. What is the quality of the Old Ford water? In your judgment is it suitable for domestic purposes?—I have not gone into the analysis of the water, I have left that to those able chemists who have made so many analyses of it; but as a rule I have not found the water complained of generally, and during the time of the cholera very numerous families known to me drunk that water with impunity.

4196. It has been stated that a certain leakage took place from one of the cuts into the reservoir supplying the district with water; have you any knowledge of that fact?—I believe it was the fact, indeed I know it was; I was down at the works at the time it was discovered.

4197. Would not that have a very serious depressing influence upon the health of the inhabitants?—There is no doubt that it would have a depressing influence upon the inhabitants; all impure water is so far injurious.

4198. (*Sir B. Phillips.*) You are a general practitioner, I presume?—Yes.

4199. In your experience among your patients generally, did you find any instances of the deleterious quality of this water during the progress of the cholera?—No, excepting amongst a certain class and in a certain locality. The poor and impoverished people living in certain habitations were the class more especially obnoxious to cholera.

4200. And you found that those people who were living in very inferior habitations, badly fed, badly clothed, and intemperate in their habits, were the classes of people who were more liable to be attacked and struck down by the cholera than others?—I did.

4201. And you attribute to those causes rather than to the water the prolonged outbreak of the cholera?—I consider that those causes made them susceptible of the choleraic poison whatever it may be.

4202. You think that the patients had less power of resistance when they were attacked?—Yes, just so. But amongst the better classes who were intemperate whatever might depress their power of life, intemperance, or fatigue of body or mind, or any excesses, if they were in a bad state of health, they would also be susceptible of the disease; but those in a good state of health, living temperately, amongst the better classes I do not find as a rule were at all susceptible of the disease.

4203. (*Chairman.*) We are to understand that there were a variety of causes in operation to produce a general depressing influence on the health of the inhabitants?—Yes.

4204. And thus to reduce the resistant force of the constitution?—Yes.

4205.—And when the disease made its appearance they became easy victims to its power?—Yes.

4206. But are you not able to say whether the water was an important element in the production or increase of the cholera?—I cannot positively speak on that point. I would rather speak in the negative sense in reference to the water producing the cholera.

4207. But yet you do speak to the fact that the water supplying that larger area was contaminated by leakage from one of those leaky cuts?—Yes.

4208. Would not that in itself be sufficient to account for a vast amount of disease?—Yes, but I must observe that the leakage in the reservoir may have been, and I believe had been, going on for some considerable time, perhaps some years, unknown to the company.

4209. And I suppose that that in itself would be sufficient to account for a great many zymotic diseases which have been prevalent in that locality?—Yes, there is no question that it would aggravate them.

4210. (*Mr. Harrison.*) I think you describe it pretty fully in page 12 of the pamphlet which you have handed in, which is a special report by you to the Limehouse District Board of Works; you say "Now "whatever dispute there may be about the origin of "the cholera and its relation to the water supply "there can be none as to the localities where it has "found victims. In the parish of Limehouse there "are nine streets with 100 deaths; in Ratcliff "seven with upwards of 60. One character runs "through the whole of them as a rule; like Eastfield "Street, North Street, and Northey Street, Lime-"house, and William Street, Ratcliff, they are "either built over slush and filth, or the flooring and "joists rest on the earth itself or but a very few "inches above it. These are the places where "always has come fever just as they have lately been "in turn the fatal resorts of cholera." I take it from that that your view is that this unhealthy habitation is much more likely to breed cholera and a much more certain element of it than any question with regard to the water supply?—Most emphatically I say so.

4211. (*Chairman.*) Has your attention been directed to the mode of storing water by the poor in those localities?—Yes, that has come under my supervision.

4212. They keep it in tubs, do they not?—No, not in tubs, in water butts or tanks.

4213. Are the houses generally supplied with cisterns?—Yes, with cisterns or water butts; no tubs are allowed—we never allow it.

4214. When you say "we" do you mean the district board?—Yes, the Limehouse district board, at my suggestion.

4215. Are you of opinion that the constant supply would be a preferable mode of distributing water to the intermittent system?—Decidedly.

4216. What are your reasons in favour of that view?—I think that the storage of water by the poor more particularly is objectionable in itself, and renders it liable to contamination as well as from the decomposition set up, especially in hot weather.

4217. The water itself would have the power, would it not, to absorb the gases which are generated in that locality?—Just so.

4218. (*Sir B. Phillips.*) You recommend, do you not, in your report that certain streets, courts, and alleys should be wholly demolished as incapable of sanitary repair and unfit for habitation?—I do.

4219. And that all factories, yards, and works of every description engaged in operations on animal matter or giving rise to offensive effluvia should be at once abolished?—Yes.

4220. That is really the conclusion at which you have arrived?—Yes.

4221. In fact your idea appears to be that the disease is rather generated by those influences of which you speak than by anything connected with the water?—I think that atmospheric causes have had mostly to do with it, in combination with the nuisances of the locality, and not the water itself.

4222. And this is the remedy which you propose?—Yes; those are amongst the remedies. There are streets in my district where it is impossible to keep out fever whenever it shall become epidemic. They are built upon filth. Perhaps the Commission will allow me to give an illustration of this as bearing upon the point. In the Burdett Road, Limehouse, there are perhaps 300 houses built fairly on a good foundation, and little or no cholera was to be seen there. A little way off, about a short quarter of a mile, there are about 120 or 140 houses, four-roomed houses occupied by mechanics and that class of people, and they are built as it were upon the earth. There is no exaggeration in the report which I have made. I there found that the cholera was fearful; there were numerous deaths, and diarrhœa was very prevalent; whilst in the Burdett Road, only a short distance off, there were scarcely any cases.

4223. (*Chairman.*) They have a sewer down the Burdett Road, have they not?—Yes, they have.

4224. And the basements of the houses are all drained?—Yes. In an adjoining district some years ago there was a quantity of gravel taken out and a large pit left. An invitation to fill this pit up was issued by the owners of the property by giving the men a ticket for beer, and this immense place was very soon filled up with all kinds of filth, and it has since been built over and occupied. I say that the slaughter of human life there was frightful.

4225. Our inquiry is specially directed to the question of the quality of the water, and I understand from your statement that you are of opinion that the water was not the principal cause of the outbreak of cholera in that district?—Just so.

T. Orton, Esq.
30 May 1867.

4226. But that it is due to other causes, or rather to a combination of causes?—Yes. Perhaps you will allow me to say further, that in the Limehouse establishment for children last summer they were drinking water, as the master tells me, all day long, because they had nothing else to drink, and there was not one case of diarrhœa or cholera.

4227. How many children were there in that establishment?—400.

4228. Were they drinking the Old Ford water?—Yes.

4229. Was it subject to any filtration?—None at all. There is an iron ladle attached to the tap, and they were drinking all day. In the Stepney union at Bromley there were 700 or 800 persons drinking this Old Ford Water in a similar way, and there were not more than three deaths from cholera, and those arose from the parties going out to Shadwell to nurse some friends who were then suffering from cholera, and they brought it back with them; and those were very aged people, as I have mentioned in my report, whilst round about this very workhouse where the houses are built upon the wretched foundation which I have described, there were numerous deaths. It was fearfully felt there, and just round about the Limehouse workhouse in the same way the mortality was very great. In the Poplar union again I am not aware—and I saw the medical officer yesterday, and he was not aware—that there was one death in the Poplar union workhouse, whilst round about in those houses so wretchedly built there were numerous deaths.

4230. (*Sir B. Phillips.*) Are you the only medical officer for the Limehouse district?—Yes, I am the only medical officer.

4231. What is the population in your district?—Nearly 60,000.

4232. (*Mr. Prestwich.*) Are there not equally wretched localities in the district supplied by the upper reservoir of the East London Company?—I am not acquainted with them, but the houses of this class that have been built about London have much of the same character.

4233. What I want to know is whether you have districts equally wretched in that part of London which is supplied by the other reservoir, and whether you found the cholera to be more or less prevalent there?—I have no knowledge of the other districts, I confine my observations more particularly to my own.

4234. Your duties do not go beyond the Limehouse district?—No.

4235. (*Chairman.*) Is there anything further that you would wish to suggest to the Commission?—There is one point that I should like to mention to the Commission. In the third week of July the chairman of the Sanitary Committee said to me: "When will this fearful mortality end? When will "there be a change in the disease?" I said, "I will "stake my reputation that immediately the wind "shifts to south south-west and rain comes it will "subside."

4236 And was that prophesy realized?—Yes.

4237. I suppose it was based upon previous observation?—Yes.

4238. (*Sir B. Phillips.*) How long have you been medical officer of your district?—Between seven and eight years.

4239. (*Chairman.*) And did that dryness of the skin and the other symptons depart immediately the wind changed?—It all gave way, and people, as I have expressed it, breathed more freely, and felt a relief as if something had left them. The chairman of the district board is quite ready to confirm that; in fact, I have mentioned it in my report.

The witness withdrew.

S. W. Leach, Esq.

STEPHEN WILLIAM LEACH, Esq., examined.

4240. (*Chairman.*) You are the engineer, as we are aware, to the Thames Conservancy Board?—Yes.

4241. How long have you held that appointment?—Under the conservators and under their predecessors, the corporation of the City of London, for about 25 years.

4242. As engineer, you have had your attention naturally directed to the condition of the river Thames?—Yes, I have.

4243. And to the volume of water now abstracted from the river for the purpose of supplying the inhabitants of the metropolis?—Yes, I have.

4244. Have you observed any evil effects of that abstraction of that water upon the scour of the river?—No, I have not.

4245. Are the companies working up to their statutory limit, or have they power to take a larger quantity than they now take?—They have power to take a considerably larger quantity than they have ever yet taken.

4246. And do you apprehend any evil arising to the volume of the river, supposing they were to exercise their power to the extent that Parliament has authorized?—I do not.

4247. Do you think that the Thames basin and the Thames stream are equal to the growing requirements of the metropolis?—Yes, I do.

4248. Do you mean the Thames, in its present condition, apart from any question of storage by means of reservoirs?—Yes, I think that reservoirs would be valuable auxiliaries; but I was about to say that for the greater part of the year the largest abstraction that the water companies can make could not be detected in the volume of the river.

4249. Have you made a section of the river at any point and gauged the daily flow?—Yes, I have.

4250. At what point?—At Teddington, below the lock.

4251. Have you any tables showing the daily flow?—Not showing the daily flow, but I have a register.

4252. How often have you taken the quantity?—I have occasionally gauged the flow of the stream, and I have had daily observations made which give me the height of the water. I do not mean to say that I have worked out those observations to show what the daily flow is, but they give me a very good idea of what quantity of water is passing.

4253. If you have made a careful section of course the height of the water would give you the volume flowing?—Yes.

4254. And have you tested that so that it could be worked out to give the number of gallons passing that point daily?—Yes, but it would be far better done at a weir.

4255. But they have no weir sufficiently perfect to enable you to do that?—No, the Teddington lock was constructed merely with a view to navigation and not for gauging purposes.

4256. Consequently a great deal finds its way through which you cannot gauge?—Yes, it is so very irregular that it cannot be done.

4257. Are you aware of the fact that Mr. Simpson has made a section of the river above the point where the water companies are taking the water, and has made very frequent observations?—Yes, he has daily observations taken, and has had for many years past.

4258. Have you compared your observations with his?—No, I have not compared them; at least not recently. A good many years ago I did.

4259. Can you speak at all from your observations as to the minimum quantity flowing at Teddington?—The minimum quantity that I have ever gauged has been 380,000,000 gallons in 24 hours.

4260. Have you gauged the river in flood, so as to know the maximum?—No, I have not.

4261. Have you taken the mean condition of the

river?—No, a low condition of the river; I will not say the lowest, but a decidedly low condition of the river.

4262. I suppose that two or three times the quantity you have mentioned would come down in flood?—Yes, and more than that.

4263. (*Mr. Harrison.*) Is that the quantity above or below the point where the companies take their supply?—Below.

4264. (*Chairman.*) Have you gauged the stream at any other point?—I have gauged it just below Kew Bridge.

4265. Are there any tributaries between that point and Teddington?—There is one branch of the Colne, and of course there are the springs which would rise in its course over about six miles; I gauged it at Kew Bridge in the beginning of October 1865, which was a dry season.

4266. Is the difference considerable between Kew and Teddington?—It was somewhat over 450,000,000 gallons when I took it at Kew, which was six miles below Teddington.

4267. There would of course be more water in the river there than at the upper point?—Yes, one would reasonably expect there would be much more there.

4268. (*Col. Harness.*) Do you know what the volume was that was then flowing at Teddington?—No, I do not, on that day.

4269. (*Chairman.*) Having regard to the increase of population in the metropolis, and the increased use of water by substituting waterclosets for cesspools, and other sanitary arrangements, you have no doubt that the Thames basin is equal to supply the whole of the metropolis?—I think so.

4270. And that it might be so taxed without injuring the scour of the river?—I think so.

4271. Are you of opinion that it is or is not necessary to have those auxiliary aids, such as storing in time of storm in reservoirs at different points?—I think that they would be desirable auxiliaries, because you would be utilizing a quantity of water which now runs to waste, and you would unquestionably assist the volume of the river materially in very short water time.

4272. What is the effect that is produced in the lower or tidal part of the river by those floods?—To scour the channel of the river; we notice that the large quantities of mud that collect on the foreshores during summer time are carried away by the winter floods.

4273. Have you observed the effect of the floods below London Bridge in the Pool?—Yes; a land flood has a decidedly cleansing effect there, and very particularly when it is connected with ice.

4274. (*Col. Harness.*) Are there not deposits in other parts of the river from the land floods instead of a scour?—There is a slimy deposit on the land which the flood waters cover, but I do not think there is anything beyond that.

4275. You do not observe that there is any material deposit?—No.

4276. (*Chairman.*) Do you think that by the principle of storage and equalizing the flow of the river you would lose the benefit of those special scours to which you have made reference?—No, I do not think we should.

4277. You think that you might store sufficient water to give an ample supply, and yet have the benefit of those floods for scouring purposes?—Quite so.

4278. Are there any points up the river which are peculiarly suited in your judgment for the formation of reservoirs for storing?—Yes; there is a district beyond Oxford which is well qualified for the formation of reservoirs.

4279. Is it a clay district?—Yes.

4280. How many miles is it above Oxford?—I think the most eligible point would be about 10 miles beyond Oxford.

4281. Then you would fill your reservoirs from the river itself when in flood?—Yes.

4282. And then you would store it and allow it to flow when the water went down or the supply was deficient?—Quite so.

4283. Would there be any difficulty in keeping the water in a state of purity all the time?—I think not if the reservoirs were made as they ought to be made, sufficiently deep, and I would have them made very deep, certainly not less than 20 feet in depth.

4284. And do you think that at that depth the water would sustain itself in purity?—I think it would.

4285. I presume the object of having it deep is to avoid the decomposing effect of a high temperature?—Yes; when the water becomes warm there is a great tendency in the weed to grow, and when it is shallow the light gets better access to the weed also, and that tends to make it grow.

4286. But with a depth of 20 feet you think that that would be obviated?—I think it would; and I say so because I have noticed that in parts of the river where the water is very deep, there is little or no growth of weed.

4287. Will the repairs which you are now carrying out at the several weirs and locks up the river have a tendency to improve generally the condition of the river?—I conceive they will have a very material effect in improving it.

4288. Captain Burstal told us that you had served a notice upon all the towns up to and including Oxford requiring them to divert their sewage within 13 months from the date of notice, but of course subject to an appeal for further time if any of them should require it?—Yes, that is so.

4289. It would of course greatly improve the river if that sewage and other contaminating matter were diverted?—It would improve the condition of the river, but I think that the contamination has been very much exaggerated. In those country towns there is no regular system of sewage generally. The majority of the houses drain into cesspools; and really there is no very large outfall in any case except at Windsor; there a more perfect system of drainage has been carried out, and there is a most offensive outfall.

4290. Still there must be a very large amount of ammonia flowing into the river notwithstanding the cesspools, because of the overflow which you must necessarily catch in the river. A cesspool is very soon filled, and though not filled withsolid excreta still there is an overflow, and that must find its way into the river ultimately?—The ground absorbs a good deal of that. I have noticed the outfalls of some of the larger towns, such as Abingdon and Wallingford, and although they are unquestionably offensive, still there is not that volume which would be the case with a similar population in London.

4291. Is the volume of water in the river sufficient to deodorize it?—Yes, it very soon loses any contamination.

4292. Take Windsor for example, where there is a discharge of a considerable amount of sewage out of their drains, have you observed the condition of the river at the point of discharge, and also a few miles down?—Yes I have.

4293. How soon in your observation is the effect of sewage destroyed by its flow and admixture with the water?—At Windsor it is discharged into a most unfavourable point in the river, where there is little or no stream at ordinary times. At times of flood of course there is more stream, but usually there is very little stream there, and the matter which is passed out of the drain floats about in the river there to a very great and very disgusting extent.

4294. Is there an eddy there, or what?—No, there is a weir just immediately below, which deadens the stream sufficiently to deprive it of the force required to take what is floating away. Two miles or even a mile below that I could see no traces whatever of the sewage.

4295. Was it all broken up and destroyed?—Yes, and taken by fish, and so on.

4296. Is it the habit of fish to take up matters of

S. W. Leach, Esq.

30 May 1867.

that kind?—Yes, you generally see persons fishing close to the outlet of a drain. I think that the operation of the Act of 1866, which prohibits the discharge of sewage into the river, will have a very beneficial effect. If some such provision had not been passed I can quite understand that as the system of waterclosets was extended and a more perfect system of drainage was carried out, the river would rapidly become much more contaminated; but the powers contained in that Act will, I hope, put an effectual stop to the pollution of the river.

4297. You are aware that at Kingston they contemplated a regular system of drainage, and pointed their outfall to the river?—Yes.

4298. What steps have they taken to deal with their sewage?—The most recent steps that they have taken have been to attempt to induce Parliament this session to give them a greater time for dealing with the question. I do not know whether they will succeed in it.

4299. Have they a bill before the House now for that purpose?—No, but the conservators have a bill before the House, which they were bound by the Act of 1866 to bring in, prohibiting the discharge of sewage into the river between Staines, where the Act of 1866 ceases, and the western limit of the metropolitan district.

4300. (*Sir B. Phillips.*) By means of storage auxiliaries what quantity of water do you think might be safely taken from the river *per diem*, the water companies being permitted now to take something like 100,000,000 gallons, although they only take 50,000,000 gallons?—They take more than 50,000,000 gallons in the driest seasons.

4301. What quantity do you think they might take?—With storage reservoirs I should think that the river might be maintained in a perfect state if they took 200,000,000 gallons in the 24 hours.

4302. (*Chairman.*) They might take, might they not, the additional 50,000,000 gallons, which they are entitled to take under the Act, without any injury to the river?—I think so. The portion of the river which would be affected by it is very short, varying from three to six miles above Teddington Weir. The whole of the rest of the course of the river would be entirely unaffected by it, so that it is only that limited space which would be immediately affected.

4303. It is the space I presume from the tidal point to the point where they take the water?—Yes; they take it mainly at two different points. There is also the question of interfering with the supply of water in the upper part of the tideway; and I think that more complaint has been made from persons residing in that part than any other of the ill-effects which have been presumed to follow the abstraction of the water. In my opinion they have been quite mistaken upon that, they have attributed to the abstraction of the water from the river that which has arisen from an entirely different cause. The fact is that the Thames in the tideway for the last 30 years or more has been undergoing very great changes. The bed of the river in and about London has been depressed by the excavations which have been made in it, but at the upper extremity of the tideway it has remained pretty nearly the same. The consequence is that the inclination from that point down to where the excavations have taken place has become much greater, and consequently the stream is much more rapid, and therefore instead of the normal flow of the river passing off gradually as it did formerly, it now runs off very quickly, producing a much sharper stream in the upper part of the tideway towards the time of low water than there used to be, and whatever supply there is of water is consequently carried off more rapidly.

4304. You find, do you not, a great improvement in the condition of the river within the metropolitan district since the sewage has been diverted by the works of the main drainage?—There is an immense improvement to the westward of Woolwich, but at the outfalls themselves and below them, the condition of the river has deteriorated.

4305. The volume of sewage discharged is very large there?—Yes, it is inevitable that it should be so.

4306. (*Mr. Harrison.*) Are you aware of any very minute experiments which have been made lately by Mr. Bateman with respect to the quantity of water flowing over Teddington Lock?—No, I am not.

4307. Then you are probably not aware that he has calculated that in dry seasons the quantity does not exceed 305,000,000 gallons?—I have heard it stated so.

4308. But even assuming that to be as an exceptional case the minimum, there would be no difficulty by service reservoirs in keeping that as the minimum under all circumstances, that is to say, assuming that the companies were to take 200,000,000 gallons, you could, by service reservoirs in exceedingly dry seasons, make up that deficiency?—Yes.

4309. Looking to the interest which you have in the conservancy of the river, you would not be at all afraid of allowing the companies to take 200,000,000 gallons, provided they were under the obligation, in case they did take such a large quantity, of bearing the expense of constructing and maintaining the necessary reservoirs to compensate for what they took away in dry seasons?—I think that the condition of the river would bear that perfectly well; it would be maintained under such circumstances in a perfectly good condition.

4310. With regard to the weir at Teddington, I have understood that you are making provision now by which you can accurately gauge the amount of water which will pass over it—is that the case?—No, it would be rather an expensive thing to make it a perfectly good gauging weir; but as it will not be very long before it will require rather expensive repairs, I have no doubt the conservators would approve of a plan which should make it a perfect gauging weir. I think it would be a most desirable thing to have a daily record of the flow of water there.

4311. The companies having at this present moment the power of taking 100,000,000 gallons daily from the river, would you give us your opinion as to whether they could take a larger quantity than that without compensating reservoirs?—I think they might. The part of the river affected by the abstraction is so limited that I think, supposing any inconvenience did arise, which I really do not think would be the case, it might be obviated by the execution of works in the upper part of the tideway which would compensate for any ill effect that might be produced. Such works would consist of deepening the river so as to prevent the water from running off as I have described so rapidly as it does at present, and, of course, the same operation would bring the tide in sooner, and keep a full river longer.

4312. Either by the process of deepening below the weir or by compensating reservoirs above, you consider that there would be no reason whatever why 200,000,000 gallons, if necessary, should not be taken from the river above Teddington?—200,000,000 gallons would be rather an extreme quantity to take without any compensating reservoir, but with compensating reservoirs I should have no question whatever about it.

4313. (*Col. Harness.*) If the minimum flow were retained at its present amount, you think that no injury would be done to the navigation?—I think not.

4314. Even though the minimum flow were continued over a greater number of days?—No, I think that there would be no material inconvenience; certainly not to the navigation.

4315. (*Mr. Harrison.*) You have examined all the upper sources of the Thames, have you not?—Yes, I have.

4316. Is the point you mentioned above Oxford the only one where you think reservoirs could be conveniently constructed?—I think there are other points where they might be constructed, but I am not so sure about the strata at other points being suitable.

4317. You perhaps have not gone into the detail of the nature of such a reservoir or calculated the quantity

S. W. Leach, Esq.

30 May 1867.

which it should hold?—Not minutely. The fact is, that you could not come to a satisfactory conclusion unless you had borings made, and a proper and accurate survey made, and that has not been done yet.

4318. Still you have had your attention sufficiently directed to the subject to give with perfect confidence the answers which you have already given?—Yes. I have looked at that part of the river particularly with reference to this subject, and assuming that the Oxford clay prevails there which is said very confidently to be the case, and which I have no reason whatever to doubt, I think that it would be an advisable place for reservoirs. There is one point which has occurred to me of which the observation of the chairman has reminded me, with regard to the improved condition of the water in the tideway; whether the supply which London requires might not be economised by drawing water from this lower part of the river for watering streets, flushing sewers, and such purposes as that, where it is not necessary to have water of the purest quality.

4319. (*Chairman.*) That would involve, would it not, a duplicate system of mains?—Yes, I am quite aware of that, but the water which is used for watering streets, and those other purposes, has to undergo all that expensive process of filtration which is adopted to render it fit for drinking; and it has to be brought from a great distance as well; and it has often occurred to me that when the condition of the river here should be improved as it is now there would be no harm whatever in taking water from this part of the river and applying it to those purposes to which I have referred.

4320. For street and fire purposes you think it would be quite good enough?—Yes, and for some manufacturing purposes also.

The witness withdrew.

Adjourned to Wednesday next, at 11 o'clock.

Wednesday, 5th June 1867.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND, K.G., IN THE CHAIR.

Sir JOHN THWAITES.	Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.	THOMAS ELLIOT HARRISON, Esq.

JOSEPH PRESTWICH, Esq.

GEORGE REMINGTON, Esq., examined.

G. Remington, Esq.

5 June 1867.

4321. (*Chairman.*) What is your occupation?—I am a civil engineer residing in London.

4322. Are you connected with any society?—I am a member of the Institute of Civil Engineers.

4323. Are you engineer to any water company?—I am not at present. The last position I held was that of Civil Engineer to the Admiralty at Bermuda, and I was there for five years.

4324. Have you turned your attention to the question of water supply to the metropolis?—I have.

4325. Have you done so with the view of procuring it from any particular district?—Yes.

4326. Have you prepared a scheme for bringing it from any place?—I propose to bring it from the hills of Derbyshire, to collect it at a point above Mill Dale, on the Dove, from the summit of the Derbyshire and Staffordshire range of hills.

4327. What is the distance to London from the first point where you propose to take the water?—135 miles.

4328. What height should you be there above Trinity high water?—586 feet above Ordnance datum.

4329. Where do you propose to deliver the water for the supply of London?—On the top of Barnet Hill, about 10 miles from London.

4330. What height would you be at Barnet?—300 feet above Ordnance datum.

4331. (*Sir J. Thwaites.*) Do you mean at Totteridge?—Adjoining Barnet; what is called Barnet Hill.

4332. (*Chairman.*) What tract of country do you propose to get your water from, at the extreme point of Mill Dale or the river Dove? What extent of area do you propose to put under contribution?—262 square miles.

4333. Have you had any rain gauges taken in that district?—No, I have not taken the rainfall.

4334. Would you not consider that to be rather an important feature?—No doubt it would be requisite to determine accurately the quantity of rainfall to know the precise quantity of water to be obtained.

4335. What quantity of water do you propose to supply per day at Barnet Hill?—About 100,000,000 gallons. I have put it down in the paper which I sent in to the Commission as 83,000,000 gallons, or one-sixth of the rainfall on the 262 square miles, but in round numbers I would take it at 100,000,000 gallons per day.

4336. How do you arrive at anything like a conclusion that you could get such a quantity from this district?—By assuming that the rainfall upon those hills is 48 inches per annum.

4337. Is that the minimum rainfall or the mean?—The mean, taking the year through. I assume that to be the average, but I have no doubt that if it were accurately taken it would prove to be considerably more. It has been gauged at Uttoxeter, which is on the Dove, but Uttoxeter is very low, and there the rainfall is about 30 inches, and I have assumed the quantity falling on the high district to be 48 inches.

4338. Do you think that an average fall of 48 inches would enable you to supply 100,000,000 gallons per day at Barnet?—I do, and that is only one-fifth part of the quantity that falls. I only propose to take one-fifth part of the rainfall on those hills, leaving the remainder to flow into the river.

4339. Do you mean that 48 inches is one-fifth of all that fall?—No, I only take one-fifth part of the quantity that falls, and that would give 100,000,000 gallons a day.

4340. Do you mean that one-fifth of the 48 inches is equivalent to 100,000,000 gallons a day?—That is so.

4341. What description of country is it between Mill Dale and Barnet?—I have a section of the whole country through, which I took some years ago when I explored the country for a railway from London to Manchester, and a part of that section I have here, which is upon a very large scale.

4342. Then how do you propose to bring the water?—Partly through pipes and partly through open aqueduct, and partly through tunnel.

4343. What description of pipe?—I consider that two pipes of about 6 feet diameter each would be sufficient to bring that quantity of water to London.

4344. What was the total cost of your plan?—I put it at 5,000,000*l.*

4345. And to take how long in the construction of

G. Remington, Esq.

5 June 1867.

the works?—I have hardly gone into the question of time.

4346. When you get the water to London, what do you propose to do with it?—To distribute it by pipes on the present principle of mains.

4347. What do you intend to do with the existing companies?—I think that the best plan would be for the Government to purchase the interests of the existing water companies.

4348. Assuming that the Government have bought up the existing water companies and you are with your water at Barnet Hill, what is the next process?—The next process would be I expect also that the Government would carry out the new water scheme, and unite the two systems into one.

4349. When you say that, do you mean that the Government should give you 5,000,000*l.* for your water when you have brought it to London?—I mean that the Government should expend 5,000,000*l.* in carrying out the plan to bring the water to Barnet.

4350. Then we are to understand that this is a scheme which you propose that the Government should undertake?—It might be done by private enterprise, but I myself think that the water supply would be better in the hands of the Government.

4351. Dealing for a moment with your scheme by which you tell us you could bring the water from a particular point to London at a cost of about five millions of money, by what parties do you intend your scheme to be carried out, or are we to understand you to say that the Government should do it all?—I say that it might be done by private enterprise, but I think it would be better that the water supply should be in the hands of the Government.

4352. How do you propose to collect the water at Mill Dale?—I propose to erect weirs across the various streams which come down to that point at different levels, and by that means collect all the water that is required upon the usual plan of dams and weirs.

4353. Do you propose to construct any large reservoirs?—Yes, several. I propose to construct reservoirs upon every ridge of hills that I pass through.

4354. What size would the reservoirs be?—Taking them in the aggregate as furnishing 60 days' supply, it would require about 1,000 acres of reservoir space to supply that quantity of 100,000,000 gallons, supposing no rain to fall.

4355. I understand you to say that you would make reservoirs upon all the ridges as you go along; what would be the size of any one of the reservoirs which you propose to make, say the largest one?—I have taken them in the aggregate. I have not calculated the size of any particular one at present, but taking the whole through it would require for 60 days supply a storage of 1,000 acres of water 20 feet deep.

4356. That is over and above what would be in the rivers?—Yes; that would be the size of the reservoirs for 60 days supply supposing there was no rain during the whole of that time. There would be at least 10 or 12 different reservoirs to hold that quantity.

4357. How do you propose to fill any or all of those reservoirs?—By pipes and aqueducts from one to the other. They would descend gradually, and according to the line which I have taken they would be at Battle Flat in Leicestershire, between Burton-upon-Trent and Leicester, where there is very high ground. That would be the first, and from that point they would descend gradually, having a large reservoir upon each of the ridges between the valleys all the way to London.

4358. There appears to be a considerable amount of tunnelling in your scheme. I see you propose 45 miles of tunnel?—Yes; the tunnelling would come as cheap or cheaper per mile than the pipe work.

4359. Would you not require pipes through the tunnels?—In some cases I should, but where the fall is with the inclination I should not.

4360. What you would propose then is a tunnel in which you would have no pipe?—Yes, the water would flow through the tunnels.

4361. But how do you propose to build the tunnels?—Of properly constructed brickwork or masonry watertight.

4362. In your estimate you have put down 3,000 acres of land, but you would require, would you not, to take a great deal more land than 3,000 acres?—No, I think not. The width of the way would not be very much.

4363. Would that include severance and damage?—Yes, I think about that quantity would be sufficient, but I have not gone into the matter very minutely as to the quantity of land.

4364. That might add very considerably to the cost of your scheme, might it not?—Not very much, I think I take it at 60*l.* an acre.

4365. Could you get land at that price, which is not much more than the agricultural value?—In some cases where the tunnelling was the land would hardly require to be purchased. There would only be the compensation for passing through, the surface would remain untouched.

4366. Do you find that generally in constructing railways the proprietors do not want to sell their land if you tunnel underneath?—Of course they require compensation.

4367. Is not 60*l.* a very low figure?—Not for the land that the line would generally pass through.

4368. You talk about going through Leicestershire; is not some of that very rich grazing country?—A part of Leicestershire is.

4369. However, you say you are not bound by that estimate?—Not at all; of course this is only a preliminary approximate estimate, and therefore you must allow a little latitude upon that head.

4370. Will you give us the estimate for your scheme?—Yes. 45 miles of tunnelling at 20,000*l.*, 900,000*l.*; 68 miles of double tubing, including brickwork and masonry for piers, at 30,000*l.*, 2,040,000*l.*; 6 miles of open aqueduct, including brickwork and masonry, at 25,000*l.*, 150,000*l.*; 2 miles of cutting at 10,000*l.*, 20,000*l.*; 14 miles of reservoir, including all work, 50,000*l.*, 700,000*l.*; 8 miles of cutting, embankment, and tunnelling, to unite the rivers above Mill Dale, at 17,000*l.*, 136,000*l.*; embankments, dams and weirs, sluices, &c., 350,000*l.*; 3,000 acres of land at 60*l.*, 180,000*l.*; making together 4,476,000*l.*, and contingencies, 447,600*l.*; forming a total of 4,923,600*l.*

4371. You have made plans and sections as we understand for the whole way from one end to the other?—Yes, I have.

4372. Have you gone into all those figures carefully?—Yes, I have.

4373. Are those the figures which you are prepared to state will be the result of your calculation?—I consider that upon the whole 5,000,000*l.* would be about the expense of carrying out the scheme.

4374. But the 180,000*l.* which you have put down for land you cannot pledge yourself to?—No, but it will make very little difference in point of quantity, I believe.

4375. That you say you have not gone into, but with regard to the works, which is a matter which would come under your immediate cognizance as engineer, you would know whether they could be constructed for that amount which you have put down?—Yes, I consider that the prices generally which I have put down would be ample.

4376. Have you gone into the subject minutely or only generally?—I have worked it out from a section which I have sent in to the Commission.

4377. What is the quality of the water?—I cannot speak to that, but I know that the water there is very bright and very clear from my recollection of it, I have explored all those valleys.

4378. Is it hard water or soft water?—It is not very hard water, and it cannot be, because it is caught as soon almost as it falls from the clouds to the surface, and it does not pass through the rocks.

4379. But you get some of the water from the rivers, do you not?—I get it all from the rivers, but it is caught so soon almost as it falls by taking it at the head of those streams.

4380. However, you are not prepared to speak to the quality of the water?—No.

4381. What is the character of the country at the head of those streams whence you intend to take the water?—It is a wild country.

4382. Is there any agriculture there?—Sheep-feeding on the hills is all I know of.

4383. What is the geological formation of the country?—It is the carboniferous system all through; in some places the limestone, and in some places the millstone grit. It is altogether a carboniferous series of rocks.

4384. In the course of the route between this place and London, do you go through any mining district?—Yes; the line would pass through Ashby-de-la-Zouch, which is a mining district.

4385. Would not the water be polluted thereby?—No, not at all, because the channels would pass over, and could not have any communication with the mineral district.

4386. You mean that it would be in closed pipes?—Yes.

4387. Are there any mines at the head of those rivers whence you take your supply?—I do not know of any, but there may be. I cannot speak to that.

4388. But would not that fact have a bearing upon the question of whether the water was pure and wholesome or not?—No doubt it would, but I cannot imagine that it can be very much contaminated, knowing that that is a beautiful district for fishing, and where there is good trout and grayling, generally speaking, you find the water very pure. Cotton says that the river Dove is the finest river in England for trout and grayling.

4389. But you are aware that when Cotton wrote there were not so many manufactures about?—No, there were not.

4390. Cotton wrote as far back as 1759, and there have been a good many changes in the face of the country since that time?—There may have been mines opened certainly.

4391. When was the last time you were in this district at the head of this river?—It is 20 years ago, but I examined it then so minutely, that many things are quite as fresh upon my mind now as they were at that time.

4392. Although 20 years ago there were no mines opened and no manufactures up there, they might have been opened since, but you are not aware of them?—I am not aware of them, but I believe that most of the mines are lower down. At the time that I speak of I examined, I dare say, more or less, 1,000 miles of country to ascertain the best line for a railway from London to Manchester, and that led me up the Dove to its head through Buxton, and that way, and also up the Derwent from Derby to its head; and almost all the streams I personally examined. Indeed I may say I walked up the greater part of them, so that I am familiar with the district in consequence of that.

4393. Does your scheme embrace the notion of supplying any of the towns on the route between Mill Dale and London?—Yes, it would take in a greater population than any other line that could be laid out, because, first of all, going from London, it takes in Barnet, Luton, Bedford, Wellingborough, Kettering, Market Harborough, Leicester, Burton-upon-Trent, and Uttoxeter, and from Uttoxeter there are not many towns until you get to Buxton.

4394. To supply those towns which you have mentioned you would want more than 100,000,000 gallons, would you not?—Yes; of course my estimate has only reference to London; but if the towns on the way are to be taken into consideration, then, of course, the pipes would have to be larger, but a much larger quantity of water could be got than I think of bringing to London. I only bring one-fifth part of the rainfall, as I said before.

4395. What do you allow for compensation to keep up the rivers and for evaporation, and so on?—They have too much water, and I should say they would be glad to get rid of it, because all the low valleys up to Uttoxeter and Doveridge, Tutbury, and those places, are often inundated, and they would rather be without the water.

4396. They would rather not be inundated, but supposing at times when there was no question of inundation, but in times of drought, would not your scheme drain the river altogether?—No because I would have reservoirs up above to take the water during heavy rains.

4397. You take 48 inches as the average rainfall, and one-fifth of that 48 inches you take to be 100,000,000 gallons for London?—Yes; the remainder would go into the present streams as at present which eventually fall out into the Humber.

4398. You mean that you would take the surplus water in fact?—Yes, I would take the surplus water.

4399. Do you apprehend that you would not reduce the rivers at all?—It would reduce them at floods; but then I say it would be a benefit rather than otherwise.

4400. If you reduced them at floods, would you not also reduce them at other times, and would not the same operation which reduced them at floods reduce them at average times?—It would not be absolutely necessary, because by having storage reservoirs above Mill Dale, which might be the case, we could supply water to the rivers so as to equalize the flow.

4401. When you say "which might be the case" you mean that that would be part of your scheme?—Yes.

4402. Do you mean that you would fill the reservoirs at flood times and not get water from the rivers at ordinary times?—Not when there was a very great scarcity; but generally with moderate rains I think it might be spared up in that district without injury to any one of the streams.

4403. You take a quantity of water at flood times and fill the reservoirs, but in ordinary times would you also take the water?—I would when it could be spared; but water cannot be obtained anywhere without taking it from some existing purpose to which it is applied. Therefore, that would apply to every plan. I mean that if you take water for one purpose you cannot have it for another purpose. But I think, that by taking the water from that district it would do less injury than in any other district, because taking the river Humber, the Trent runs down to the Humber; but there are no very great ports upon the Humber above Hull, and therefore it would do no injury, but in the case of the Thames, if you take the water away from the Thames you are doing an injury to the port by abstracting the scouring power.

4404. From your recollection of the ground between Mill Dale and London should you say that the works would be heavy?—Not particularly heavy, nothing impracticable or impossible.

4405. We know that no civil engineer ever yet admitted that anything was impossible, and there is a scheme now as you are aware for making a railway to France underneath the channel?—Yes, and I happen to be the proposer of it.

4406. Generally speaking, from one end of this scheme to the other are the works heavy in an engineering point of view?—Not at all.

4407. Looking at the section, there appears to be a great quantity of tunnelling?—The line laid down upon that section referred to the railway which I mentioned, but the line for the works which I propose for the water is upon the section which I sent in to the Commission and I have merely shown you the larger section to show the section upon which I base the plan that I sent in.

4408. This section which I hold in my hand, the larger section, is a copy of a section which you drew

G. Remington, Esq.

5 June 1867.

for the purpose of making the railway from London to Manchester?—Yes.

4409. With the usual gradients I suppose?—Yes. The railway line is shown by the red line, but the water lines as far as that section goes are laid down in blue lines.

4410. But it would appear that there is a considerable amount of tunnelling?—Yes, there would be a good bit of tunnelling, but tunnelling for such a purpose I consider would not be expensive.

4411. Just before you get to the 114th mile the red line seems to cut the top of a hill; then it seems to go with a slight decline for a considerable distance, but over the tops of the hills and valleys too?—Yes, it would partly be on embankment and partly through pipes on piers. I should put the pipes over the valleys on piers.

4412. This section before me does not show that?—No, but the section which I sent in is more detailed than that, if you will refer to it.

4413. What average fall do you get per mile all the way?—If it was one uniform fall it would be 2·12 feet per mile.

4414. Is that fall enough to carry it all that distance?—Yes, plenty; it would come at half of that.

4415. Are there any valleys that you go down and up by syphon?—Yes, several.

4416. Would the 2·12 feet per mile enable you to do that?—Yes, but at those points, in some places, the inclination would be more.

4417. You mean that 2·12 feet would be the average?—Yes, that would be the average, taking it right through.

4418. That would be the greatest fall?—I dare say in some places it would be double that. Supposing there is a syphon pipe starting from this high reservoir at Battle Flat, and going down the valley and up to the next ridge upon the opposite side, it would be as the difference of those two levels of the reservoirs.

4419. (*Mr. Prestwich.*) Have you any map of the district?—I have the Ordnance map of the whole district from London to Derbyshire.

4420. Does it show the position of the reservoirs?—Generally it does. I have not marked the places, but I could point out the general position of them.

4421. You have several reservoirs which you propose to construct?—Yes, I propose to have one upon each of the ridges separating the valleys.

4422. Do you go as far as the High Peak?—I catch the water from the High Peak; but it would be conveyed from a point lower down, at Mill Dale which is lower than the High Peak.

4423. And also, do you take it from the valleys to the west of Bakewell?—Yes, above Bakewell from Monsal Dale on the Wye and Calver on the Derwent.

4424. Those valleys are all upon the millstone grit, are they not?—Yes, a great part of them are on the Derwent.

4425. Whereas the valleys of the Dove are on the limestone?—Yes, partly, and there is some millstone grit there.

4426. Therefore the waters probably would be of a mixed character; some of them would be soft and others hard?—Yes, they would be of a mixed character no doubt. I consider that the water of the Dove is brighter than the Derwent generally.

4427. You made the observation that owing to the rapid flow of the rain off from the hills the character of the ground would not probably much affect it, but have you any reason to suppose that that would be the case?—The inclinations of the hills are so rapid that the water has not time to percolate much through the surface of the soil before it is down in the valleys.

4428. But whenever it falls upon a calcarious surface, it always immediately takes up a certain quantity of carbonate of lime, does it not?—In some cases that might be so.

4429. Have you any reason to know that it would be otherwise?—No.

4430. It is on the opposite flanks of those hills that the Sheffield and Holdfast reservoirs are fixed, is it not?—Yes, it is upon the same mountainous range of hills.

4431. Therefore the water in that range would be of a very similar character?—Yes, very similar. I might observe that the town of Bristol is supplied from a district similar in its geological character to what I propose at the Dove, that is to say, in the new works that were carried out by Mr. Simpson some years ago at Bristol from the Mendip Hills. The water from the Mendip Hills falls upon the same description of limestone.

4432. From your experience should you have any preference for either hard or soft water in the supply of towns for general purposes?—My own opinion is, generally speaking, that water the purer it can be got and the more directly from rain without impregnation the better. When I was at Bermuda I carried out a great number of tanks, the whole of the water there is rain water.

4433. That is a matter of necessity at Bermuda, is it not?—It is a matter of necessity; the water is stored in tanks holding about 3,000 tons some of them, and the water keeps as pure as possible in those tanks, and it is so soft that the people never think of boiling it for washiug clothes, and I believe it is, generally speaking, liked by all naval men visiting Bermuda for watering the ships and so on.

4434. You have taken out of a supposed rainfall of 48 inches about 8 inches of the quantity of which you would avail yourself for the supply of London. Is there any reason why you limit yourself to so small a proportion as that?—Not at all, I only took that as the basis of my estimate, because I considered that about 83,000,000 gallons per day was the quantity supplied to London by the existing companies, and I found that that would take about one-sixth part of the rainfall upon the hills of Derbyshire above Mill Dale.

4435. Supposing you are right in your estimate, what quantity do you consider that you might safely reckon upon out of the rainfall of 48 inches?—I do not see why we might not take at least one-half if it was required.

4436. You are probably aware that it has been stated to us in evidence that it is hardly safe to calculate upon the average rainfall, but that you must take rather the minimum quantity in any one year?—It is safe to do so, but I have made provision for that in the size of my reservoirs. There is never a month I should say passes in this district without rain.

4437. You have not made any gaugings yourself, but are there not gauges at Buxton and Bakewell and in several parts of Derbyshire?—I cannot find any record of them, but there may be.

4438. What is the nearest town where you have any record of the rainfall?—At Uttoxeter, which is down below considerably. Generally speaking, I consider that the higher you go the more rain you get.

4439. Then you think that the quantity that you now reckon upon might be doubled?—Yes, we might take double with safety.

4440. But also you reckon, do you not, that various large towns might be supplied?—I do.

4441. Supposing London were to require a supply of 200,000,000 gallons a day, you would hardly have any to spare for the other towns according to your estimate?—Not without taking more; not without taking water from the rivers, but that is not likely to occur for many years; but there is the river Churnet also, from which a deal of water might be drawn by extending a branch aqueduct up above Alton as stated in the paper I sent in to the Commission, that would give an additional area of collecting ground of about 70 square miles, and add greatly to the supply.

4442. Do you know whether many of those towns in the district through which your line passes require an improved supply of water, for example, Derby, Burton-on-Trent, and Stafford?—I have no doubt they do, but I have not been there recently so that I cannot speak positively.

ARTHUR SYDNEY ORMSBY, Esq., examined.

A. S. Ormsby, Esq.

5 June 1867.

4443. (*Chairman.*) You are a civil engineer?—Yes.

4444. Will you inform the Commissioners what societies you are connected with?—I am a member of the Institution of Civil Engineers, of the Royal Irish Academy, and an honorary member of the Academy of Sciences at Philadelphia.

4445. You have published a pamphlet, have you not, upon the water supply of towns?—Yes.

4446. And also with regard to the supply of water to troops in India and in the colonies?—Yes.

4447. You have, therefore, devoted a considerable amount of attention to the subject?—I have.

4448. Are you connected with any of the water companies?—No.

4449. Have you been engaged in laying out any waterworks in any part of the country?—Drainage works I have, but not specially waterworks. It is a branch of civil engineering, and as such I have attended specially to it.

4450. I mean you have not carried water from any part to any towns either in this country or Ireland or America?—No; but I beg leave to remark that experience of works may be attained by observation as well as by actual charge of them. I have seen and carefully examined all the principal waterworks of America, India, and Australia, as well as the other countries I have visited in the pursuit of professional information and experience, and I think I can say, without boasting, that I have seen and examined more works of the kind than any other engineer now living.

4451. Are you prepared with any scheme to bring water to London?—I am.

4452. What is your scheme for bringing water to London?—I propose to give a limited supply only for drinking and cooking, and to economise the other sources of supply to such an extent as to meet the requirements of the population.

4453. How do you propose to economise the water?—By devoting it to the special purposes for which it is sought.

4454. That is to say for drinking purposes?—No, the present supply I assume to be solely calculated for common use; for washing, for animals drinking, for steam engines, manufactories, &c., and that class of purposes. I submit a memorandum showing the consumption of water at present, from which it will be seen that the three West End districts are the largest consumers of water:—

From the "Times," May 29th, 1867.

The Registrar General has to acknowledge the courtesy of the London Water Companies, who have furnished him with the average daily quantity of water supplied for the month of April 1867; thus, according to their account, 94,103,007 gallons, or 427,553 cubic metres of water, equal to about as many tuns by measure, tons by weight, were supplied daily; or 975 litres, rather less than a ton by weight, to each house, and 139 litres (=30·5 gallons) to each person.

Companies.	Number of Houses supplied in		Average Daily Supply of Water in Gallons during the Month of	
	March 1867.	April 1867.	March 1867.	April 1867.
Thames.				
Chelsea - -	26,783	26,821	7,499,400	7,884,900
West Middlesex -	36,515	36,515	8,374,912	8,667,501
Southwark & Vauxhall	70,984	70,997	13,100,000	13,200,000
Grand Junction -	26,450	26,918	8,624,220	9,003,981
Lambeth - -	37,549	37,712	8,374,600	8,696,000
Other Sources.				
Kent - - -	33,864	34,243	6,088,776	6,140,625
New River - -	112,971	113,208	21,121,000	21,947,000
East London - -	91,975	91,975	18,942,000	18,563,000
South Essex* - -	978	986	189,023	184,023

NOTE.—The water includes the supply for manufactures and for various purposes other than domestic consumption. In April 1867 the total number of houses supplied was 438,389; average daily supply of water, 94,103,007 gallons. This return, as compared with that for the previous month, shows an increase of 1,298 ouses and an increase of 1,978,099 gallons of water supplied daily.

* The secretary to the South Essex Waterworks Company, writing in October 1866, said:—"We have not extended our mains at present west of Romford." In other words,—not to London.

ANALYSIS of the above Return, showing the Quantity of Water consumed per House in the Districts supplied by each Water Company in April 1867.

	Number of Houses.	Gallons per House.
Grand Junction - -	26,918	334
Chelsea - - -	26,821	279
West Middlesex - -	36,515	237
Lambeth - - -	37,712	230
East London - - -	91,975	202
New River - - -	113,208	186
Southwark and Vauxhall -	70,997	186
South Essex - - -	986	186

4455. Do you mean that the existing water companies should supply water for those purposes and for those purposes only?—Yes, for those purposes alone.

4456. What is your proposal with regard to water for drinking and cooking?—I propose to obtain that from rain water upon a principle which I believe I have discovered myself, that is to say, the non-absorbing principle. I propose to cover over a certain area, as is shown in sketch 6 in the pamphlet which I have handed in, with an impenetrable surface, and to collect the water from the surface into reservoirs.

4457. The space of ground which you represent by the dotted line on the plan is supposed to represent how much?—That depends upon the number of inches of rainfall, and the number of population to supply.

4458. We are now dealing with the supply of London, with a population of 3,000,000; having that in view what do you intend this to be?—I put down the daily consumption at 3,000,000 gallons, and the evaporation and waste, at say 10 per cent, 300,000 gallons, making the total daily consumption 3,300,000 gallons, and this at 6·25 imperial gallons per cubic foot would be equal to 528,000 or say 530,000 cubic feet, which divided by 8 gives 66,250 cubic feet or the quantity required at each station in order to give one gallon per head per diem, and this amount must be collected, stored, and distributed at each station. In order to provide for contingencies I assume that there will be 90 days supply required at each station. The rainfall in that time or three months may be taken at six inches, or 135,744 gallons per acre, and as 3,300,000 multiplied by 365 gives 297,000,000 gallons or the total quantity required per annum, then 135,744 divided into 297,000,000 would give 2,188, which is the area in acres of the entire collecting surface, and this divided by 8 gives 274 acres as the area of the collecting surface at each station.

4459. You state that you enclose the piece of ground represented by the dotted line. My question is what size is the piece of ground which you so enclose?—2,188 acres, or less than $3\frac{1}{2}$ square miles.

4459*a*. Will you explain further this drawing?—I propose to cover the surface either as shown in sketch 5 with a roof of glass and iron and wood, or with a prepared surface as is shown in sketch 6, or by a combination of both as is shown in sketch 7. The rain falling upon that surface passes off from the inclined portions into the tube which is shown by the dotted line, and passes down through an opening into a pipe connecting with the reservoir itself.

4460. What is the size of the reservoir?—If one reservoir were made it would be 35 acres, but if separate ones were made they would be 5 acres each.

4461. What do you propose to do to supply London with water for drinking and cooking purposes?—I propose to have eight collecting grounds of 274 acres each in different directions around London, or to have one collecting ground of 2,188 acres at one place, whichever may be considered most advisable in an economical point of view.

4462. (*Sir J. Thwaites.*) What would be the yield from the 2,188 acres?—It would be equivalent to 1 gallon per head per diem for a population of 3,000,000 persons.

A. S. Ormsby, Esq.

5 June 1867.

4463. One gallon per head is not sufficient, is it?—It would be sufficient for drinking and cooking purposes.

4464. (*Chairman.*) You would, of course, keep the two supplies separate?—Yes, quite separate.

4465. Do you think that that would be practicable?—Yes, quite practicable.

4466. Take a London house; you propose that one part of the water supplied should be for drinking and cooking?—Yes.

4466*a*. And another part for waterclosets?—No, the water that is supplied for common use is at present supplied for waterclosets, and there is no necessity for altering that arrangement further than to prevent waste; but the additional supply which I propose is for drinking and cooking, which would be supplied within the house, while that supplied at present would be, as it is at present, outside the house.

4467. Would yours be a constant supply?—Yes, and it would be equivalent to the number of persons in the house. For instance, if there were five persons in the house, the landlord or the occupier would arrange with the water company to supply a gallon per head for five persons, and he would receive that by meter, according to the plan which is adopted at Rouen and other places.

4468. Will you explain your plan further; after collecting the water in those tanks, how do you get it to the house?—By pipes from the district reservoir.

4469. And you propose, do you not, to have eight around London?—Eight collecting grounds or one complete collecting ground.

4470. Where would you propose to have that one complete collecting ground?—On Salisbury Plain or some other equally suitable place. It is impossible to give the exact localities without making proper surveys, the expense of which is too considerable to incur on speculation only.

4471. Then we are to understand you to say that you have not made any calculation as to what the cost would be of supplying London with drinking water from Salisbury Plain, taking one gallon per head per diem for a population of 3,000,000?—No, I have not; at least, not one that would be at all suitable to lay before the Commission. I could not do it; it would be simply misleading. I have made a rough estimate, which may be some guide, and nothing more.

4472. What is your rough estimate?—4,800,000*l*.

4473. What is the height of the reservoir at Salisbury Plain above Ordnance datum?—It is about 280 feet, as near as I could get it.

4474. And what height do you propose to be when you get to London?—Not having the necessary levels and surveys I have not gone into that question, but there is no difficulty about doing so, because of the very considerable height it is above London. I can suit it, in fact, to anything that is required, but as water is not required at a high level for drinking and cooking purposes, I simply propose to take it at as low a level as economy may suggest in the construction of the works.

4475. When you say that you do not require a high level, how would you give it to the houses?—By pipes from the distributing reservoir, in the same way that the present pipes are laid, until subways are constructed to receive the pipes.

4476. Would you not require pumping?—The present supply does, but the future supply for drinking and cooking purposes would not have any pumping. Being collected at such a level, it would be delivered by gravitation to the basements of the various houses in and around London.

4477. You think that a collecting ground 280 feet above datum would be high enough?—With regard to Salisbury Plain, I have not been able to get the exact levels, but they are from 300 to 400 feet, and I believe that a collecting ground at that height would be sufficiently high to enable the water to be delivered to the basements of the houses in London.

4478. I understood you to say 280 feet, now you say 400 feet?—The collecting ground varies there; I have a statement of the actual height, and it varies considerably.

4479. (*Mr. Harrison.*) What is the minimum height?—The minimum height is 280 feet.

4480. (*Chairman.*) What is the rainfall in that district?—The average rainfall during 10 years is 28·69 inches.

4481. Is it regularly gauged?—Yes; the returns from various authorities are given, and the names of those who have made observations on the rainfall around the Plain.

4482. (*Mr. Harrison.*) What is the minimum rainfall?—25 inches.

4483. (*Chairman.*) When you have collected this water, what would be the gradient of the watercourse between Salisbury Plain and London?—Really I have not gone into that question; but it is one that can be easily regulated.

4484. It is an important fact, is it not, to discover how you get the water to London from Salisbury Plain?—Of course it is a very important fact. It is a fact connected with the complete design, the surveys, the levels, and so forth that are necessary to be made in order to make the estimate for the works; but it is sufficient for my purpose, I venture to say, to prove that it can be done.

4485. Is not it an element in the case as to whether it can or cannot be done, to know what the fall of the water would be?—Of course it is.

4486. And that you say you have not determined?—I have not got the levels and I have not got the surveys.

4487. Might it not result in your finding that you could not bring water from there to London?—No, not at all.

4488. Why so?—Regulating valves can always be put to prevent too great a velocity; besides, the distance is 84 miles.

4489. But supposing there is not fall enough, what would you say?—There is fall enough; 200 feet in 84 miles is quite sufficient.

4490. What gradient will that give you?—It is a quite sufficient gradient for any point in London.

4491. (*Mr. Harrison.*) You assume, do you not, that when you get it to London you will have to pump it again?—No, as it is unnecessary to supply it at any point in London higher than that at which it could be delivered by gravitation, which is all that is needful for drinking and cooking purposes.

4492. (*Chairman.*) Have you not an approximate estimate of what the scheme would cost?—Yes, I have. I assume that the cost of forming a collecting ground, similar to sketch 6, would be 1,200*l*. an acre.

The witness delivered in the following estimate:

ROUGH ESTIMATE.—One acre of collecting surface.—See sketch No. 6 in pamphlet on Water Supply by me.

	£	s.	d.
Land	60	0	0
Earthwork 820 c. y. at 6*d*.	20	10	0
Concrete in cement 810 c. y. at 9*s*.	364	10	0
Slates squared and set in cement 4,840 square yards at 2*s*. 6*d*.	605	0	0
Gutter 55 yards at 10*s*.	27	10	0
Brick enclosing wall 63 c. y. at 25*s*.	78	15	0
	£1,156	5	0

Or say 1,200*l*. as the assumed cost of collecting surface per acre; then

	£
Constructing collecting surface of 274 acres at 1200*l*.	328,800
Reservoirs say	30,000
Piping and other distributing works	150,000
Extra work, say	50,880
Surveying, &c. &c.	40,320
Cost of one station	£600,000
	8
Probable cost of 8 stations	£4,800,000

4493. How do you propose to carry this scheme out; that is to say, who are to make the reservoirs?—I propose that a public company should be formed precisely

similar to the other water companies, so that London would possess, instead of eight water companies, nine, similarly constituted in every way, with only this addition, that the accounts should be more strictly looked after to prevent the possibility of those difficulties which have already occurred in connexion with public companies.

4494. Do you propose a more accurate audit?—Yes, there should be a Government auditor at each board, or a Government director, somewhat similar to the Indian railways, so that no expenditure should be incurred without the knowledge of the Government. I am not an advocate for Government interference, but the dreadful amount of fraud in the management of limited companies renders it most desirable that some check should be put upon it.

4495. What sort of country would you have to come through; is it an easy or a difficult country?—I propose to go along the railway, and to make arrangements with the company to lay pipes along the side of the line.

4496. But how could you do that?—By negotiation with them. I should say that there would be no difficulty.

4497. Surely a railway company would not be enabled to make any such arrangement under the powers of their Act?—Then I should lay the pipes so that they would not injure the railway; I would generally take the line of the railway as near as may be, provided it was found suitable; but it is impossible to state the exact line without a survey.

4498. A railway company is incorporated for certain purposes, and they have power to levy tolls under the provisions of their Act. They clearly would not have the power to enter into negociations to lay down pipes for water?—Not unless they received that power from the Legislature. Supposing in the Act of the proposed company powers were taken to negotiate and to admit of pipes being laid, if found suitable, upon the ground of the railway company, it could be done. There is always a certain amount of surplus ground connected with every line.

4499. Would that be possible?—Yes. I am unable to give any statement with regard to the actual location of the works, and only a general idea of the construction of non-absorbing surfaces for collecting and storing water, for the simple reason that no surveys have been made, and that without the most detailed surveys any estimate that I could give would only be misleading the Commission.

4500. Supposing it were practicable to get the water to London, you say that you would deliver it there in the same manner as the other companies do?—Yes.

4501. And you would have another rate?—Yes.

4502. So that in point of fact there would be two water rates?—Yes, there would, but the pure water rate would be small compared with that for fresh water.

4503. What number of gallons per day do you calculate upon supplying?—3,300,000 gallons per day.

4504. Taking the population of London at 3,000,000, you propose to give a gallon per head per day?—Yes.

4505. Then you would propose, would you, to take away from the existing water companies the right of giving 3,000,000 gallons per day?—Yes, or I would increase their power by giving them an additional 3,000,000 gallons a day. The reason as I understand of the present inquiry is that the water companies are not able to supply the requisite amount of a sufficiently pure description.

4506. That is the subject which we are investigating, and we have not yet arrived at that conclusion, but you state that there would be, according to your scheme, nine water companies in lieu of eight?—Yes.

4507. And the ninth water company would take power to give to the inhabitants of the metropolis 3,000,000 gallons a day?—Yes.

4508. That being water which would be exclusively used for cooking and drinking purposes?—Yes.

4509. The other eight existing water companies would therefore not have the power of supplying the 3,000,000 that would be used for cooking and drinking purposes?—Certainly not.

4510. But if they say that they can do it, how are you to compensate them for taking away from them the profit that they make out of the 3,000,000 gallons a day, which you propose to give to the ninth company?—I do not see any necessity for compensating them, because of the simple fact of their not being able to supply the class of water that is required for drinking and cooking.

4511. But you are aware that their argument is that they can?—But we have the most eminent testimony to show that they cannot. We have the analyses of the different waters to show that they are absolutely supplying poisonous water, and that they are not able to supply water of such purity as is suitable for drinking and cooking.

4512. You by your scheme say to the eight existing companies, You shall not under any circumstances supply a particle of water for drinking or cooking?—Yes.

4513. Upon what principle would you say that?—Upon the principle that the water companies are not able to supply pure water at present.

4514. That is the point which they dispute?—But then when it is proved not only theoretically but practically, that they are not able to do so, they have no right to complain.

4515. In point of fact your scheme is based upon the fact, or rather I should say upon the assumption, that the existing water companies cannot and do not supply water for drinking or cooking that is fit for those uses?—It is, but I would rather take the word "fact" than the word "assumption." If you believe in analytical chemistry, you must say it is a fact, but if you deny its existence as an exact science, then you may take it as an assumption.

4516. Then take it as an assumption. I say that your scheme is based upon the assumption that none of the water companies can or do supply pure water to the metropolis?—As a matter of course it is.

4517. What do you consider to be water that is unfit for drinking or cooking?—Anything but rain water.

4518. Why do you come to that conclusion?—From practical observation in different parts of the world that there is considerably less mortality where rain water is used than where other water is used, and that where bad water is consumed the mortality is especially great; besides this, it is contrary to common sense to admit that rivers, which are the open sewers of the country, can give pure water, no matter how much it may be filtered, and I appeal to medical and chemical evidence in support of this view of the case.

4519. But do you mean that all water except that which is rain water is bad?—For purposes of health I do, that is to say, for drinking and cooking.

4520. Have you any figures to show us what effect the water supplied by any of the water companies in London has had upon the population?—The Registrar General's returns, showing that a very large mortality exists in the districts supplied with the East London Company's water, and with the other water that are taken at a point where the Thames is considerably polluted. I refer to those in support of that view.

4521. In the case of the other companies whose water is not taken where the Thames is polluted, is there a very high rate of mortality in their districts?—I have not remarked it.

4522. Is not that a feature in the case, because you state that all the water supplied to London is bad?—For the purposes of drinking and cooking it is.

4523. That is, so far as health is concerned?—Yes.

4524. But would London as a whole, excluding the East London, district, show that there is great mortality consequent upon the supply of water?—I do not condemn all the water of London upon the ground of the great mortality from it, but I do condemn it upon the

A. S. Ormsby, Esq.

5 June 1867.

separate analyses of the water supplied by each different company.

4525. Can you give us an analysis of the water of any one company not the East London. Take the New River, for instance?—This is a chemical point, and I refer to Professor Parkes's hygiene, in which he describes the composition of water. In fact, I may say that your Grace's question would be best met by the opinion expressed in his work. I condemn the water supplied from all rivers and from all sources except rain, in which I am supported by the opinion of Professor Parkes.

4526. What is the character of the water supplied to London by the New River Company?—I have not got with me the last analysis of that water.

4527. Or can you state the mortality in the district so supplied?—No, I did not bring the return with me. I did not suppose that the question would have been put to me.

4528. It is a very important feature in the case, is it not?—Yes, of course it is, but I submit that the question belongs more to the medical man than the engineer; the doctor states the disease and its effects with a suggestion as to its cause, the analytical chemist confirms the doctor's view, says that water is the cause of the disease, and they both say to the engineer, we want water, limited in quantity but unlimited in purity, while the ratepayers say, let us have it as cheap as you can.

4529. What is the character of the rain water which you would supply to London?—Pure.

4530. What is the composition of it chemically?—The chemical composition of all rainwaters differs very slightly.

4531. I want to know what the character of the rain water would be when you deliver it in London; how would it be chemically described?—I do not see any other way to describe it than as pure water; rain water is pure.

4532. What do you call pure water?—Rain water, and Dr. Arthur Hassall says, when asked, "You "would regard rain water as one of the purest waters? "Yes, as the purest of all water except distilled; and "I would observe that the quantity of organic matter "contained in the water of the two butts submitted "to examination, bore no comparison to that present "in river water, being at least a hundredfold less." Professor Way says, "I have before stated my belief "that rain water collected in a pure atmosphere, and "on surfaces uncontaminated with decaying animal "or vegetable matter, or with soot, &c., is the most "perfect form of water. It is in fact the nearest "approach to distilled water; but having the advan-"tage over artificially distilled water of being well "aërated, and therefore agreeable to drink. I consider "the water of Farnham, of which we are speaking, to "be rain water."

4533. What do you call the water supplied by the companies?—I call it river water, because it has come in contact with the earth, and therefore has received certain impurities.

4534. What is the character of the water supplied by say the New River Company?—That is river water.

4535. What is it composed of?—I have not with me the last analysis, but I can supply it; I would, however, call it simply fresh water. As a general reply to your Grace's questions on this point, I beg to refer to the important evidence contained in the Appendix (No. 111) to the Report on the supply of water to London, published in 1850, by the authority of the Board of Health. I did not study that Report until some time after I had published my pamphlet on water supply.

4536. Is it hard or soft?—It varies; the chemical composition of the water varies at different seasons of the year; in fact on different days it varies and almost at different hours.

4537. You probably have not gone into that question?—I have not, as it is a question for the analytical chemist who can speak with an authority that no engineer can attempt with propriety. The simple facts are that the London water is impure, and as it appeared to me that rain water was perfectly pure that was all that was required.

4538. The London water you state is impure, but how do you prove it to be so?—I refer to the Registrar General's reports in support of that view. I also refer to the inquiry made with reference to the East London water by Captain Tyler.

4539. Here is the analysis of the metropolitan waters in the Registrar General's report. "The above quantity "of water supplied by the Chelsea company had been "after its descent to the earth as rain contaminated "with sewage or manure matter equivalent to 2,195 lbs. "of average filtered London sewage; but by gradual "oxydation partly in the pores of the soil and partly "in the Thames or its tributaries, and partly in the "reservoirs, filters, and conduits of the Chelsea com-"pany, this sewage contamination had been converted "into comparatively innocuous inorganic compounds "before its delivery to the consumers"?—Dr. Odling states, and Dr. Letheby agrees with him, that it is impossible to deprive water of its impurity when once that impurity has been contracted. In fact I have taken the opinion of those eminent chemists as establishing beyond doubt the necessity for a perfectly pure supply of water for drinking and cooking for the metropolis.

4540. We may take it generally, I suppose, that yours is a scheme which you have not been able to go into with any degree of accuracy in consequence of the large expense that would attend it?—Yes. It would cost about 20,000*l.* to make the necessary surveys which I would have made similar to that of others, but I did not think it wise to lay such imperfect documents before your Commission.

4541. But your scheme is based generally upon the assumption that the eight companies are to be told that they are not to give any water for drinking or cooking?—Decidedly.

4542. And that upon the ground or upon the assumption that none of the water which they do give or can give is fit for either drinking or cooking?—Yes.

4543. And that its impurity leads to great mortality?—Yes, combined with other causes.

4544. Is the average mortality of London very high as compared with other places?—No, but I attribute that to the fact of the population being scattered over a very large area, and that one area compensates for the other.

4545. They all I suppose drink water in some form?—Yes.

4546. If the water is so bad would it not have an effect upon the mortality of the population though they may be spread over a large surface?—It would and it does. For instance, the mortality in the eastern districts is much greater than in the western.

4547. But are not the people in the eastern districts very much overcrowded, and are not the houses very small and dirty?—It is true that that is the case.

4548. Would not it be likely to be the fact that if the water which is now supplied to London is so bad and so injurious to health the mortality in London would be great?—Perhaps it might.

4549. But at the same time you say that the mortality in London is not great?—Not as an average, but in a particular case it is.

4550. Taking London as a whole they all have the water supplied by the water companies, and if the water is bad the whole of London consumes, and mortality is caused by drinking bad, would it not follow that the mortality would be great?—Yes, but then there are other causes for the mortality of cities than bad water.

4551. But you say that the mortality of London is not great?—As an average it is not great; it was 19 per 1,000 for the week ending May 27th 1867. In other cities it varies from 20 to 35 per 1,000, and it was 33 per 1,000 in Glasgow the same week that it was 19 in London, notwithstanding that the former city is supplied from Loch Katrine with what is supposed to be the purest water under the sun. The public rate of mortality then would appear not to be an evidence of the purity or otherwise of the water.

4552. Then do you think that the mortality of London is not a test of whether the water is bad or not?—I don't think it is; not as a general principle. I look upon it that the water is positively bad analytically. It is not fit for drinking, and therefore it should not be supplied for that purpose.

4553. Still people do drink it, and yet the mortality of London is not great?—That is a difficulty which I cannot elucidate. I have looked at it in various points of view, and unless it be from increased temperature in some places above others, the predominance of noxious manufactures, and the increase of those employed in trades which are admitted to be injurious to the human health, I cannot discover a solution of it, but I can say this: there is the analysis of water made by the most eminent men, and there are the opinions of Dr. Parkes, one of the most able writers on the subject, and he says that pure water is rain water.

4554. You mean that rain water is the only pure water?—Yes. I find on referring to the reports on the mortality of the British army that where rain water is supplied the mortality is considerably less than where any other description of water is supplied.

4555. Will you tell us where that is given?—It is given in the table at page 23 of my pamphlet. At column 2 it will be perceived that the death rate at Gibraltar is 5·68, and at Malta it is 6·53. Those two places are in the same hemisphere, and those two places, according to column 6, are supplied with rain. Referring to the Mauritius, the death rate in column 2 is 11·74; that is supplied, as appears by column 6, with rain and well water, rain water principally. The mortality there is very much lower than either in Ceylon or in India, all of them being in the same hemisphere.

4556. But do you mean to put the climate of the Mauritius on a par with the climate of India?—It is very little better. I have been there and I assure you I would just as soon live in India.

4557. There are a great many considerations that come into the comparison, are there not; for instance, where the troops have come from, what state they are in when they get there, and so on; all these are points to be considered are they not?—Yes, of course they are; but the general practical view of the case is that where rain water is used there is very much less mortality than where well water or river water is used, or in fact where any other supply is obtained. Take the case of troops on board ship for example; perhaps you will allow me to refer to a remarkable instance, given by Dr. Parkes, referring to three vessels which left Algiers with soldiers on board. He says, at page 56, "The case of the Argo, recorded by Boudin, is an "extremely strong one. In 1834, 800 soldiers in good "health embarked in three vessels to pass from Bona, "in Algiers, to Marseilles. They all arrived at "Marseilles the same day. In two vessels there were "680 men without a single sick man, in the third "vessel, the Argo, there had been 120 men; thirteen "died during the short passage (time not given), and "of the 107 survivors no less than 98 were disem-"barked with all forms of paludal fevers, and as "Boudin himself saw the men there was no doubt of "the diagnosis. The crew of the Argo had not a "single sick man. All the soldiers had been exposed "to the same influence of atmosphere before embark-"ation. The crew and the soldiers of the Argo were "exposed to the same atmospheric condition during "that voyage; the influence of air seems therefore "excluded. There is no notice of the food, but the "production of malarious fever from food has never "been suggested. The water was however different; "in the two healthy ships the water was good. The "soldiers on board the Argo had been supplied with "water from a marsh, which had a disagreeable taste "and odour; the crew of the Argo had pure water." That I look upon as one of the strongest facts in proof of the assertion that impure water produces cholera. I might, however, refer to many statements that have been made to me by medical men, the most remarkable of which I have from a surgeon-major R.A., who accompanied General Havelock when cholera produced such ravages amongst the troops. My own experience in the Punjab confirms this in the most conclusive manner.

A. S. Ormsby, Esq.

5 June 1867.

4558. There is no doubt that good water is much better than bad, but taking your scheme generally, for that is the only way in which we can deal with it, you think it practicable to have a non-absorbing collecting surface, and you would bring water from Salisbury Plain to London?—Yes, or from eight collecting grounds around London of a smaller area.

4559. You would confine the use of that water for drinking and cooking purposes, and you would preclude the eight existing water companies from supplying any water to London for either cooking or drinking?—Yes.

4560. And your scheme you think would have to be carried out by a public company?—Yes, so as not to interfere with the present companies. I am, however, convinced that all municipal questions—water, light, education, &c.—ought to be under one Board of Commissioners, two of whom should be appointed and paid by the Crown, and the third to be elected and paid by the ratepayers. This opinion is the result of observing the practical working of elected boards in America, Australia, &c. I regret extremely that I cannot give more particular details of the application of my plan to any particular locality, but, as I before said, either the work should be done perfectly, so as to have actual facts to work from, or it must not be done at all.

The witness withdrew.

James Simpson, Esq., examined.

J. Simpson, Esq.

4561. (*Chairman.*) You are a civil engineer and have been in practice for upwards of 40 years?—I have.

4562. Are you president of the Institution of Civil Engineers?—Yes, I have passed the president's chair.

4563. Are you the engineer to the Chelsea and Lambeth Waterworks?—Yes.

4564. And to the Bristol, Cardiff, Cambridge, Aberdeen, and several other works?—Yes.

4565. Therefore your experience I suppose we may say is second to none in this country?—I have had a great deal of experience in water engineering, in fact I have devoted my lifetime to it.

4566. Were you engaged in the New Water Supply to Aberdeen, I mean the works that were open last autumn?—Yes, I designed the works and carried them out.

4567. You are, of course, acquainted with the valley of the Thames, I suppose?—Yes, I am.

4568. Can you state what is the area of the watershed of the Thames?—It exceeds 2,500,000 acres.

4569. Have you gauged the water of the Thames at Kingston?—Yes, I have.

4570. What is the smallest quantity in the driest season that you have found there?—The smallest quantity was in 1864, 380,000,000 gallons per day, after the companies had taken about 50,000,000 per diem.

4571. And that from inquiries on the spot you found to be the driest season that had been known for many years?—Yes, personally I knew that it was a very dry season, but I made inquiries and I found that it had been the driest season of any one known. I made a point of going to all the fishermen and boatmen and all the oldest inhabitants, and I found that it was the lowest water they had known.

4572. What is your belief as to the possible supply to London from the Thames basin?—The supply might be taken from it up to a certain quantity, and then it might be supplemented by reservoirs to double that amount. In fact my own opinion is that from the valley of the Thames we may depend upon 200,000,000 gallons per diem.

J. Simpson, Esq.

5 June 1867.

4573. That is excluding what would be produced by the river Lea?—Yes.

4574. Would the 200,000,000 gallons per day which you say the Thames will afford to London be after arrangements had been made for making new reservoirs?—Yes. There is plenty at present to supply the companies. There is no necessity for reservoirs now, there is a very large supply of water indeed.

4575. In fact your opinion is that the Thames basin is capable of supplying to London by proper arrangements 200,000,000 gallons per day?—Yes, it certainly is.

4576. And that is exclusive of what would be supplied to another part of London by the river Lea?—Yes.

4577. What would be the amount that you would consider necessary to supply (distinguishing between the Thames and the Lea) the population of London which now is 3,000,000?—The quantity last year supplied by the different companies was 46,494,224 gallons daily from the Thames and from the Lea valley 42,253,905 gallons.

4578. Then in point of fact during the past year the supply to London, including the Thames and the Lea, was about 100,000,000?—Not quite 100,000,000 gallons; 88,748,129 gallons is the exact quantity.

4579. And you think that by proper arrangements the Thames alone could supply 200,000,000 gallons daily?—Yes; we have a very large quantity of water passing down the Thames in cases of flood. We have instances of that river rising 11 feet 10 inches above the summer level when a very large quantity of water went down, in fact, it could not be measured at that time. There is very little doubt that it increased 50 fold from the dry weather yield, perhaps more.

4580. Is there a great deal of spring water in the district of the Thames?—A great deal. All the upper sources of the Thames yield a great deal of water from the chalk and from the oolitic strata.

4581. What is the quality of that water?—It is a very good water.

4582. Can you chemically describe it?—It is not very soft water, but is about 12 to 15 degrees of hardness, and when boiled it comes down to three or four. It is a water that keeps very well; you may store it in reservoirs without any difficulty.

4583. Have you tested by Clark's process that the Thames water in its natural state being from 12 to 15 degrees of hardness, when boiled comes down to from three to four degrees?—Yes.

4584. Does it lose all that by the process of boiling?—It does.

4585. Is that an ascertained and known fact?—Yes, it has been frequently tried by chemists.

4586. Is it a fact that the water companies now contribute towards the conservancy of the Thames for the purpose of having their supply protected from being fouled by sewage?—Yes. In the first instance they paid a certain sum, four of them 300*l.* a year each, and one of them 200*l.* a year and 1,000*l.* premium, that was on the removal of their works from the tideway. Last year they came to an arrangement that they were to increase the contribution to 1,000*l.* a year each, making it in fact 6,400*l.*, the conservators undertaking to keep the river in a proper state, and to prevent sewage flowing into it.

4587. You state that there is sufficient capacity in the Thames to supply in fact four times what it does now by certain arrangements being made, would it in your opinion be advisable or practicable, supposing it were found necessary, in order to supply London with a larger quantity of water that large reservoirs should be made at the head of the supply, or on the higher grounds, that the various companies to be benefited by the increased supply of water which they would derive, should contribute to the formation of such reservoirs?—Yes; I would not take it out of the hands of the Thames Conservancy. I think it is now settled down into a very good commission, and that they will take care of the river as a public river, because it is connected not only with the lands adjoining throughout the course of the stream, but it is also a navigation which to some extent has lost its trade, from neglect, but I believe they will recover a considerable portion of it, which would, of course, go to keep the stream in a proper state.

4588. Assuming that it were necessary that one or more reservoirs should be made,—they must be made and paid for by somebody,—from your great experience would you think it right and practicable that those companies should contribute towards the construction of such reservoirs?—So far as they are benefited they certainly should contribute.

4589. *Pro rata*, according to the quantity of water they would receive, will of course have to be determined the proportion which they would have to contribute?—Yes.

4590. But you think that the execution and the maintaining and upholding of such reservoirs should be in the hands of the conservators of the Thames?—Yes.

4591. But the company should be empowered to bear part of the expense?—Yes, as they take part of the benefit they ought to bear their part of the expense.

4592. You see no difficulty in such an arrangement?—No, it is rather a Parliamentary difficulty; it is a question of dealing with a public river which I hold ought not to go out of the public hands, and of course it would require an Act of Parliament, and then the arrangements might be made. At present the Thames is in a very improved state as regards its administration compared to what it used to be, for it has passed into other hands and they are now considering what they can do with it.

4593. My question merely assumed that it would be necessary to make reservoirs, and that those would be the parties from whom the money to make them would come?—Precisely so.

4594. Is it the fact that the existing companies have under their various Acts power to take double the amount of water that they do at present?—Yes, they have each power to take 20,000,000 gallons per diem.

4595. But they do only take 10,000,000 gallons?—Yes, they take 10,000,000 gallons each daily on the average.

4596. So that until that power was exhausted it would not be a question of reservoirs?—No, and even after that I think it is a question whether reservoirs would be wanted for very many years. We may go 14 or 15 years without that extreme low water which would render it necessary.

4597. What is the state of the supply of water to the metropolis now as compared with what it was some 10 or 15 years ago?—It is about double I should say in quantity.

4598. Has it improved in quality?—Very much indeed, there is much less organic matter, and it is altogether a different state of things.

4599. Have the water companies who have got those large powers laid out any money in the improvement of their works?—Yes, very large sums of money; one of the companies that I am connected with has laid out 400,000*l.* and the other 300,000*l.* This paper, which I will hand in, contains the quantities supplied by those works.

The witness delivered in the following table:

LAMBETH WATERWORKS.

RETURN of QUANTITY of WATER supplied, NUMBER of HOUSES, and POPULATION.

Gross average *daily* quantity	8,950,000 gallons.
Quantity for other than house supply per day	1,251,000 ,,
Quantity for house supply per day	7,699,000 ,,
Number of houses	37,203
Quantity for each house per day	207 gallons.
Population	225,000
Quantity per head of population	34·22 gallons.

NOTE:—The Company supply about 5,000 houses in the country districts which take large quantities of water for gardens, small fountains, &c.

5th June 1867.

CHELSEA WATERWORKS.

RETURN of QUANTITY of WATER supplied, NUMBER of HOUSES, and POPULATION.

Gross average daily quantity - -	8,000,000 gallons.
Quantity for other than house supply per day - - - -	1,193,000 ,,
Quantity for house supply per day -	*6,807,000 ,,
Number of houses - - - -	26,900
Quantity per each house per day -	253 gallons.
Population - - - -	201,000
Quantity per head of population -	33·86 gallons.

* House supply includes stables, and about one-fourth of the houses are of the largest class.

5th June 1867.

J. Simpson, Esq.

5 June 1867.

4600. You state that the question of the quantity of water is undoubted, and that they have the power of supplying London with a great deal more than it wants is a matter beyond all question?—Precisely so. Allow me to say that the Thames is one of the finest rivers in England, and as a matter of experience I never would go to a small river if I could get water from a larger one, where the drainage ground is so good as it is in this case, and we know that it comes down in a very pure state for a very large portion of the year. It is only in excessive floods that we get any colouring at all in the water.

4601. As to the question of the supply, which you say very confidently is ample (and no doubt a gentleman of your experience and position would not state it unless he was quite satisfied of the truth of what he asserted), will you state to the Commission what grounds you have in coming to that conclusion?—From knowing the district intimately, and having been employed on it professionally for many years, and in fact I have watched the question of the flow of water in the Thames beyond what a private individual would do, I have gauged it professionally, and I have had some opportunities of observations which most persons would not have.

4602. During the last 10 or 11 years have you had constant gaugings made?—I have had a register of the water taken since 1852 every morning at 9 o'clock, so that I know the state of the river, and I have also during the last 40 years advised the Crown respecting their waterworks at Windsor Castle, which obtains its water from the Thames, and is worked by a water-wheel. I have also been consulted by many millowners on the river from time to time.

4603. Then it is a fact that since the year 1852 you have had daily gaugings taken of the Thames?—I have, with reference to the summer level, every morning at 9 or 10 o'clock.

4604. Have you it in any tabulated form that you could let us have so as to append it to the evidence?—Yes. It has been published in the report of the evidence given before the Rivers Commission.

4605. (*Sir J. Thwaites.*) You made a section of the river, did you not, above the point where you take the supply?—I did. The fact is, that many persons point to Teddington Lock as the measure of the water, but you cannot gauge it at Teddington Lock. The body of the weir is not tight, and many persons say there is no water going through when it ceases to go over the weir; but a large body goes long before it ceases there. My gaugings were taken from observations of the stream itself. I have selected a parallel part of the river; the sections are extremely good, and I depend upon them. I know that they are accurate, because I attended to them myself.

4606. Has the condition of the river where you took the section altered at all since you took it first?—No.

4607. Have you taken those daily gaugings for 11 years?—Yes.

4608. Have you a register in your office of the quantity flowing over?—Yes, I have.

4609. Can you mention the smallest quantity passing over?—The smallest gauge that I took was 380,000,000 gallons after the water companies had taken 50,000,000.

4610. Were not the gaugings taken above your point of supply?—Just above the point of supply; but there was an allowance made for the quantity that two of the companies took; the other three companies were below it. The usual flow of the Thames there in dry seasons is about from 600,000,000 to 700,000,000 gallons, it is very seldom below that; and within the last 12 months it has been about from 900,000,000 gallons to 1,000,000,000 gallons, and sometimes more than that.

4611. But taking what you would call an ordinary dry year it is about 600,000,000 to 700,000,000 gallons?—Yes.

4612. (*Chairman.*) You have heard, have you not, of the various projects that have been started for bringing water to London from various parts of the country?—Yes I have.

4613. Mr. Bateman has a scheme for bringing the water from Wales, and Mr. Hemans and Mr. Hassard have a scheme for bringing it from Cumberland; what is your opinion of Mr. Bateman's scheme, or have you looked into it sufficiently to express an opinion upon it?—I have not paid very great attention to it although I know the country extremely well and have frequently been over it. I think it is an interference with the river Severn which is of very great importance in that part of the country, and with the lower reaches of the Severn which are so liable to be affected by sandbanks; and considering the great trade and the sums of money that have been spent upon that river it seems a very questionable scheme to me whether it should be interfered with, because you would be taking from that river the very life of it. You would be taking the water that scours the stream in the most essential times you would at all events take the crest of the floods if you took no more. I think it would require a very attentive survey. It is a subject which I myself am not ignorant of, because I was engaged with Sir William Cubitt in the arrangements for the introduction of locks and weirs on the Severn. I was there for some years and I know that he was extremely anxious not to have the floods interfered with; he would rather pass them off, and the weirs were made of a very wide character with the view of passing the water quickly.

4614. (*Col. Harness.*) Which is the particular part of the Severn which would be first affected do you think?—There is navigation above, but Stourport above Worcester would be the first place.

4615. (*Sir J. Thwaites.*) Would the tendency be for the river to silt up at the mouth if the water were abstracted?—Yes, the sand banks and shoals of the Severn now are very liable to shift, and it would be a very serious injury to the trade on that river if anything were to occur to it to cause any further obstruction.

4616. Do you think that the abstraction of the flood water would have a tendency to cause the river at this moment to silt up?—I think it would, it is a matter about which I should be extremely jealous.

4617. (*Chairman.*) If your proposition is tenable, namely, that there is ample water in the Thames to supply London, and that that water is good, then there would in your opinion be no necessity for going either to Wales or Cumberland?—I think not. I think the project is open to other objections. I should doubt the possibility of bringing a large watercourse of that kind across the country, say 180 or 200 miles. We know that there is great difficulty with canals in this country. Of my own knowledge I know that in hard frost of 1813–14 the Chelsea Company on the failure of the New River supply, pumped water into the New River mains at Charing Cross, and a snow storm came on in the afternoon, and the river was practically stopped. You cannot contemplate anything with an open watercourse of that length of 200 miles.

4618. That would go rather to prove, would it not, that you would object to subjecting a population of 3,000,000 to one source of supply for water?—Yes, and it would go further than that. I believe there is a

J Simpson, Esq.

5 June 1867.

notion that it would be brought in to gravitate to the whole metropolis. Now that I do not believe, for so far as I have studied the matter, Stanmore, the place where they talk of constructing reservoirs, would be only 200 feet above the Thames, whereas in the case of the New River they must be supplying places at Hampstead 400 feet, and the Lambeth Company have cisterns 400 feet above the Thames.

4619. (*Mr. Harrison.*) Those are exceptional cases I presume?—No, not exceptional cases. They are increasing in magnitude every year; all the Crystal Palace land is upwards of 355 feet above the Thames.

4620. (*Chairman.*) The objection as to silting up at the mouth of the Severn, of course, would not apply to the Cumberland and Westmoreland scheme, but they are at a great distance from London, and of course your objection as to distance would apply to that scheme in a greater degree?—As regards the conveyance of water to London it certainly would. The Bala lake water was proposed for Liverpool, and at one time it was thought that they would convey it there, but it would have affected vested interests very seriously. The Ellesmere canal receives a very large portion of its supply from the Dee, and I question whether in dry seasons without making very large reservoirs they would be able to carry it through. I do not think they could supply the Ellesmere canal and the town of Liverpool as well, but a detail survey is certainly necessary before any proper conclusion could be arrived at in respect of that source.

4621. You know that it is alleged (and it is for this Commission to get information upon that point) that the water supplied to London is insufficient in quantity and excessively bad in quality. Would you subscribe to that doctrine?—No, I certainly do not subscribe to that because I know that so far as the companies that I am connected with are concerned it is quite otherwise. They are only too anxious to give a proper supply. But the difficulty which they experience has been with regard to the owners of small property. There is an immense difficulty in dealing with the supply of the poorer neighbourhoods and one which I confess they have never been able to surmount. Some years ago I took great pains on behalf of the Chelsea Company who were taunted with the want of supply to the inhabitants of Westminster, to lay down pipes from the mains and have water constantly on. Immediately that was done the middle men sold all the cisterns and leaden pipes, and in the next year they refused to pay the money. They said that their tenants had not the water and that they had a right to the water, and in the course of seven years the whole of that work was destroyed which cost the company 800*l.*

4622. Do you think that the constant service is a desirable thing?—It would be a very difficult thing to apply unless the companies have more power, in fact it must become a question of police, otherwise I do not see how it can be applied. We have the greatest difficulty with those small properties. It is nobody's interest to preserve the fittings, at least nobody does interfere. It is a part of the pastime of the children to injure them, and the least thing that would fetch a penny they will steal. The stealing of anything in the nature of metal goes on constantly, so much so that they even have a little crowbar to enable them to draw the nails and sell them.

4623. The quantity of water you have told us is ample, and might be doubled or quadrupled; and with regard to the quality of the water which is alleged to be had, you state that it is from 12 to 15 degrees of hardness?—Yes, it varies according to the season.

4624. What is the operation of that upon the health of the drinking consumer as compared with the use of soft water?—I can give no direct comparison. I know that it has been alleged that there is very great economy by the use of soft water for washing, and other purposes, and they say it saves the wear and tear of clothes, but I think a great deal of that is speculation. I confess, however, that I have not gone into that question.

4625. With regard to the effect of the London water, which your companies supply, upon the health of the population, do you consider it an unwholesome water?—No, decidedly not. I have drunk it myself all my life—in fact it is a water which I prefer, and the chemists have gone very particularly into that point for the companies. Dr. Letheby has analysed it in the most minute way, and I believe the water to be as wholesome as any water that we can obtain.

4626. Are you aware that it is said that the attack of cholera was owing to the badness of the water supplied to the east of London?—I have heard so, but I have heard also that the same water was supplied to another district, where there was no attack at all. At the time of the cholera I paid very great attention to it, in fact I had all the district which we supply attended to, especially at Chelsea, and I confess I did not quite believe all the cholera reports. There was a great deal stated then which we did not find to be true, and a great deal in idea. Dr. McLean, who was at that time attached to that part of the district, stated places where the cholera was likely to happen, but not a single case occurred. I took great interest in it at the time in Lambeth, to see what was the state of the case. It was alleged then that in the same street, in houses supplied with water by the Lambeth company, there was no cholera, whereas in the houses supplied by the Southwark company there was. At that time the Lambeth company had removed to their present source, and had in fact improved their supply; but I question whether what was stated with regard to that street had any foundation, because it was at the end of a competition with the neighbouring company, and we really did not know which houses were supplied by the one or the other. During the change and excitement of the competition many houses got on to our works that we did not know of. At the same time there is no question that when you can get good and wholesome water it is much better than any tainted water for the supply of the population.

4627. Are we to understand that you have heard nothing or seen any returns that would lead you to believe that the water supplied to London is bad in quality and injurious to health?—I certainly have not. I believe that a great deal of what has been stated upon that point is merely assertion without inquiry. I have been in the habit of being consulted by towns not only in England but on the Continent, and I doubt whether any city in Europe is better supplied than the metropolis either in quantity or quality. In London we have water supplied to ordinary houses on every floor, and we have not only cold water but we have hot water. We have the closet system carried to a greater extent than in any town that I know of, and the convenience of the water supply in London, and the intricacies of it, are greater than one could possibly imagine. In fact when the late Mr. Thomas Cubitt was constructing all those houses in Belgravia I was at his elbow in supplying his houses with water, and he made a merit of it that he would supply the houses in an improved way; and in consequence of that, there is no doubt, he let them and sold them to an immense extent.

4628. Am I indebted to you for the supply of water which I enjoy in Belgrave Square?—Yes, and I believe in that district we can say what some towns in Europe cannot say, that we go through the week supplying something like upwards of 27,000 houses, with only two or three complaints, and many of those arise out of people's own fault. Practically all those houses have a constant supply, for the cisterns which carry them through from day to day are supplied every day in the week, Sunday included.

4629. (*Sir B. Phillips.*) Are they supplied by the Chelsea Company?—Yes.

4630. (*Chairman.*) Would it come under your knowledge if disease were produced by water supplied by your company?—It would.

4631. Would complaints come to your company?—They would. It is a thing which the directors of the company have been extremely anxious about, and in all cases of apprehension or application to them by any authorities special attention and immediate attention is paid to the matter. We do not wait for boards or anything, even the turncock is ordered to turn on the water in case of necessity and to report and not to wait for orders at all.

4632. I understand you to say that during the attack of cholera last summer the subject received your own especial and particular attention in some district in which your company were interested?—Yes it did.

4633. And you made minute inquiries?—Yes.

4634. And could you discover that any attack of cholera was the result of your supply of water being bad?—No, I could not. At the same time it might have been, but the fact is, the habits of the poor are so exceedingly filthy that you do not know how to deal with them. Even where they have a daily supply of water the receptacles are so bad that you cannot keep the water from hour to hour in anything like a proper state.

4635. What you mean is, that it would be hard to attribute to the water the existence of disease in any poor and destitute neighbourhood as being alone the cause?—Yes.

4636. But the badness of the houses, the badness of the ventilation, and the filthy habits of the inhabitants should be taken into consideration also?—Yes, and more especially the bad drainage, because, although the drainage is very much advanced in the metropolis, the lateral drainage or the minor drainage has still a great deal more to be done to it, there are many very filthy places.

4637. Would there be any means of filtering the water if a further supply were wanted before it was brought into the pipes to carry it to London from the upper grounds?—Yes.

4638. Have you had any experience in the provisions of the Act which was passed within the last few years for compelling towns to utilize their own sewage?—It is a subject which I have watched and a most difficult subject it is.

4639. Do you think that steps might be taken with regard to the water from the head of the Thames if a larger quantity were required to ensure its being as pure a quality as it is now?—By an Act of Parliament of this session the Thames Conservancy are under obligation to the water companies to exclude sewage from the river, and not to permit the towns to drain into it, and there is no reason why they should do so. Of course they plead the expense, and no doubt it will be an expensive thing to do, because the land round many towns near London is becoming very expensive, but still in the case of Croydon they have recently purchased land to the extent of 35,000*l.* with the view of securing permanently the means of disposing of their sewage by throwing it over the land, and I do not see why other towns should not do the same. It is a question no doubt of making it profitable, and I do not think that that difficulty is quite solved at present. At Croydon they sell a great quantity of Italian rye grass which they grow on land improved by the sewage of the town, and to some extent I believe they have made a profit of it, but still I do not think that we are in a condition to apply that experiment to every town. At Croydon they are near a large population with a ready means of sale for this rye grass which they would not have in small towns. Again, in many towns the sewage manure would come into competition with stable manure which everybody would prefer for gardens.

4640. (*Sir J. Thwaites.*) Rightly you state, do you not, that double the quantity of water might be taken from the Thames than is now taken by the companies without any injury whatever being done to the river?—I believe that to be so.

4641. That would give something like 100,000,000 gallons per diem?—Yes, it would.

4642. You also stated, did you not, that even beyond that quantity water might be taken without making any special provision for storing the storm water?—Yes.

4643. Could you say to what extent the principle of abstraction might be carried without injury to the river?—It would be difficult for me to say that at present, because I do not know what the effect of the improvement of the stream will be. At present in the upper part of the stream, and all above Staines, the weirs and locks are in such a state that the water runs off directly; there is no impounding at all.

4644. But they are repairing those weirs, are they not?—They are repairing the weirs, but till we know the effect of them, it will be difficult to say positively, but I should think from 120,000,000 to 130,000,000 gallons, more might be taken without affecting the river, and without making reservoirs.

4645. 120,000,000 gallons might, you think, be taken without injury to the river?—Yes, or 130,000,000.

4646. But you believe that provision by means of reservoirs might be made so as to give at least 200,000,000 gallons per diem without difficulty?—I believe so.

4647. How many years do you think it would be before the metropolis would require a supply of 200,000,000 gallons a day?—It is difficult to conceive that we can ever arrive at that point. My mind is principally directed to the distributary pipes. Here have we been at work more than 50 years, and some companies have been at work 70 or 80 years, and we only now distribute 50,000,000 gallons. It would always be limited by the distributary pipes, but we seem to be increasing now at the rate of about doubling every 40 years, that is the rate at which we are now going on.

4648. You do not assume that the population doubles in that period, do you?—It has been going on something like that.

4649. But in speaking of the 200,000,000 gallons, assuming that 100,000,000 gallons is now the proper supply for the metropolis, that would assume that the 200,000,000 gallons would only provide for a metropolis of double the present population?—Yes, a metropolis of double the present population and double that again.

4650. I suppose the tendency of substituting water-closets for cesspools in the metropolis has for the last 30 years been going on very rapidly?—Yes, it has, more particularly within the last 15 or 20 years. I believe that in the course of five years something like 80,000 cesspools, or even more than that, were done away with in the metropolis at the instance of the late Board of Health.

4651. Did I rightly understand you to state that 200,000,000 gallons might be taken from the river without any special provision of storage?—Yes.

4652. You spoke of the Act of last session, which enables the Thames Conservancy Board to exercise some control over the towns up the river to Oxford inclusive, so as to prevent the discharge of sewage. I believe that the consideration for the payment of 6,000*l.* on the part of the Conservancy Board was the exclusion of all sewage from the river?—Yes, they undertook to bring in a bill, which they have done this session, and I believe there is no doubt that it will pass, for it has passed the House of Commons, and that will have the effect of giving them the power of shutting out the sewage practically. They will have to give 12 months' notice, and there is a certain machinery which, if worked out by them, will protect the river completely.

4653. Their obligation is not simply to bring in a bill to obtain powers, but to put those powers in force, is it not?—Yes.

4654. And the water companies would have a right to withhold the payment in whole or in part of the 6,000*l.* if the Thames Conservancy Board do not

J. Simpson, Esq.

5 June 1867.

perform their part by causing the sewage to be intercepted and preventing its flowing into the river?—I do not know what power we should have of withholding the money, but I believe morally, if not judicially, the obligation is on the Conservancy Board, and they have undertaken it, and from what I know that they have been doing, I think there is no question that they will carry it out with very good effect.

4655. We understood from Mr. Burstal that they have given notice to the several towns, having regard to those provisions in the Act, the tendency of which is to prevent the river from becoming polluted by the discharge of sewage and other matters, and that would necessarily improve the water very much, would it not?—No doubt it would.

4656. You have observed, no doubt, the condition of the river at different points, and especially at points below where the sewage is discharged; how far down the river from the point of discharge have you been able to trace the presence of sewage?—Lately there has been a great deal of flood water in the river, at least it has been 2 or 3 feet above the summer water level, and I have not been able to trace any. I think the river is in a highly improved state throughout, in fact I know it is.

4657. Especially within the metropolitan area?—It is, beyond all question; in fact, we have quantities of fish going up the river now which we had not before. When I was a boy I know that at Chelsea we used to catch smelt, and I have caught them recently at Kingston again, and that is a very delicate fish.

4658. How long a period elapsed from the time that you last caught smelt to the time of their re-appearance?—I should think 40 years.

4659. Were they formerly in a large number and in a healthy condition?—Yes; we had opportunities then of catching them, and we used to have them two or three times a week at that time.

4660. From what you can recollect of smelts 40 years ago and the smelt which you have recently caught, are they in as good condition now, do you think?—I think so.

4661. Forty years ago there was no sewage flowing into the Thames, was there?—Comparatively not; so much so that we used habitually to bathe from the banks. I have often swam across the river, and rested and come back again, but latterly I should not have done such a thing.

4662. You are probably aware that there was a penalty 40 years ago upon any one discharging sewage into the sewers?—Yes. I believe the late Mr. Saunders, who was the chairman of the Westminster Commissioners, was the principal instrument of getting the waterclosets put in, and I know he told me that the power of the human manure was so great that it dissolved everything, and it was beneficial to have it discharged into the sewers. However, the mischief did not commence exactly there. The trouble in the metropolis was when they turned on so many together into the sewers, because formerly a large number of houses had only cesspools, in fact, up to a recent date they had only cesspools.

4663. Waiving the question as to whether the application of sewage to land may or may not be a profitable speculation, as an engineer and an intelligent observer of the attempt to apply sewage to land, is it your opinion that it can be applied without difficulty to land, and might therefore be taken out of the river? Yes, it is my opinion, and I state it rather beyond that of an engineer. I have been an amateur gardener all my life; when I was at Chelsea I cultivated land and sold the produce. It was an amusement to me, and I at that time used Thames mud very largely in my garden, and I know that whenever I have been able to apply it in a liquid state, I have improved the produce very much indeed. I used to grow remarkably fine cabbages there, and I think that by attention a great deal, if not everything, can be done with it. I confess that I do not go to the extent that some people do in the application of sewage to confined areas, but I say if you have plenty of room to pass it off I believe you may deal with it, but if you are to continue manuring land with it day after day, and month after month, you will not succeed. I happen to have watched the use of it at Croydon, and that is the result of my observation there. I think they are continuing it too long; they will have to allow the land, as the farmers do, to lie fallow for some time. That land, if they dug it over and let it lie fallow 12 months, would be much better afterwards than it is now.

4664. Are they constantly applying the sewage there?—Yes; it must be a larger area, and I think for a town like Croydon 20 or 30 acres is not enough.

4665. Have they not 250 acres to apply to that object?—You will find that the quantity which they apply it to is very small in comparison with what they state.

4666. Did you observe the water running off at Croydon after the sewage had filtered through; I mean the water that passed off into the upper part of the Wandle?—Yes, I have seen it frequently.

4667. It ran off apparently in a pure state, did it not?—Not exactly pure, although to the sight it is pure.

4668. I suppose it was entirely in a liquid state?—Yes; there is no question of that, but when that water has been filtered it has been pronounced sewage after all. Of course it is much more diluted. But Croydon I think is a particular case, because they have the power of dilution there to a very large extent. Some years ago I happened to pay a visit to a place near Mansfield, which takes the sewage of Nottingham; it is the Duke of Portland's property, and a friend of mine, Mr. Farrey, who was the steward of his estate, told me, when walking over the property, that if they smelt the sewage in the morning it was then too strong to put it on the land in cultivating Italian grass. I think if you employ sewage you must dilute it well, and then you may pass the water off, and as the refuse comes off you get water slightly fouled in comparison.

4669. Confining that principle to the towns on the river Thames do you think that the water running off in the condition which you refer to would be objectionable?—I think not, presuming the process is fairly carried out.

4670. There being a large volume of water in the Thames to neutralize it?—Yes. Of course I assume that they arrest all the solid matter.

4671. Having regard to the area of the Thames, 2,500,000 acres, what do you assume to be the rainfall due to that area?—The rainfall towards the lower part is about 25 inches, and in the upper portion the rainfall that we have records of would produce an average of about 30 inches. We know that in Gloucestershire a great quantity more rain falls than is the case in this direction.

4672. What do you think would be the average on the whole of the Thames basin; would it be more than 25 inches?—I should think it would be from 28 to 30 inches.

4673. Have you calculated the 28 inches on the area referred to and compared it with your gaugings above the point where you take your water at Hampton?—No, I have not done that.

4674. Are you able to say how many inches out of the 28 are really available for the water supply?—Taking our usual quantity I should say that about 14 inches would be due to evaporation and absorption, and probably we might allow 4 inches more for other things, which would bring it to about 10 inches available. I have not calculated it but it would come to an enormous quantity of water.

4675. On that large area no doubt it would be so, but when you take your gaugings above the point where you take your water supply you of course get the net result?—That was allowed for in the gauging which I gave you; they were deducted from that and added to the other amount.

4676. But you have not worked out the quantity flowing over the point where you took your section

of the river so as to show how many inches that would be over the whole area?—No.

4677. But from observation you believe that out of 28 inches 10 inches would be available for the water supply?—Yes, I do; that would be in accordance with my observation in other districts. Of late years we have had an opportunity of applying that principle to many towns where the gravitation system has been introduced, and we know a great deal more about it now than we did a few years ago.

4678. You state, do you not, that the water of the Thames is on the average something like from 12 to 15 degrees of hardness?—Yes, according to the season and the quantity of rain in the river.

4679. But that hardness is subject to be reduced by boiling from three to four degrees?—Yes.

4680. Do you calculate that the whole so reduced would be equal to rain water for washing purposes?—Yes, I think so.

4681. And that it is simply a question of the water used for drinking purposes being from 12 to 15 degrees of hardness?—Yes. The quantity of soft water used is very small in comparison with the larger quantity required for a town. The food and drinking water we cannot of course separate from the total quantity supplied, but I doubt whether it is 5 gallons per individual *per diem*, where 25 gallons is the quantity supplied.

4682. A great many persons have no means of storing rain water, and, therefore, it passes off?—Yes, rain water is in such a state that you cannot do anything with it. I know, living out of town, I have occasionally taken houses where there is no water laid on, and the receptacles for receiving the rain water are very sooty and very filthy. I was consulted for the supply of Calais, and that was essentially a rain-water supply, and one of the most filthy things I ever investigated, and there is no doubt a good deal of disease occurred from that cause. I know that kidney diseases are very prevalent in districts where they use rain water, more especially where coal is burnt.

4683. Do you mean that it is the carbon or the nitre in the water that is deleterious?—The nitre principally, I believe, it is which acts upon the kidneys.

4684. Of course, after the testimony which you have borne, you are of opinion that there is ample capacity in the Thames watershed to yield a sufficient quantity of water for the supply of the metropolis independent of any other source?—I am certain of it.

4685. And that the water as a whole is good water?—Yes, and I am not quite certain whether I might not go to the extent of saying that it is superior to what you get from Wales, and superior to that which is supplied to the northern towns, because the water in many of them is very peaty at certain seasons. The Severn water at certain seasons is as brown as coffee, and it is not a pleasant water to drink, and if you go into Manchester you will find that they use coloured tumblers to contain drinking water, and that their object is really nothing more nor less than to conceal the colour. I know when water was introduced into Liverpool from Rivington Pike, there was a great complaint of the colour of the water. They had been in the habit of receiving the red sandstone water which is quite pellucid and as bright as a diamond; and the inhabitants complained very much about the colour of the water, and it is objectionable there is no doubt.

4686. Entertaining the view which you do as to the means that you have of obtaining an ample supply, and especially connected with the prospective improvements in purifying the river itself, you are of opinion that it is not necessary to go a distance to obtain a supply of water for the metropolis?—I am. I think it would be not only a very difficult thing, but a most expensive thing to do, and when done I question whether you would be as well off as you are now.

4687. But independently of that you have an objection to bringing water so great a distance in open cuttings, inasmuch as being liable to be interfered with by frost and by heavy falls of snow, the supply might be cut off?—Yes, and I think that so large a community ought not to be dependent for its water supply on one spot.

4688. Do you know whether the New River Company have experienced any difficulty in their river during times of hard frost?—I have not of late years heard of it. I believe occasionally they have a great deal of snow falling into their stream, but I happened to know that when a boy I went with my father to the New River in the hard frost of 1813–14, and the river was so far reduced by what I may call jelly ice that the Chelsea company were obliged to pump into their mains at Charing Cross.

4689. Was that on one occasion only?—On one occasion.

4690. Since then there has been no interruption to the flow of water, has there?—No, I believe not; I have not heard of it.

4691. They break the ice, do they not?—Yes, they break the ice. The water is interrupted in its flow very much, no doubt. I should have a very great objection to a long cutting of that kind. You would have a great deal of metal pipe, cutting, and shafts, and a great deal of trouble with it.

4692. You stated that Dr. Letheby had examined the water. Has he been employed professionally to examine the water of your companies?—Yes, he has.

4693. Has he been employed professionally to examine the water of any other company?—Yes, of all the companies. I believe it is the most complete analysis of the kind which has been made.

4694. Has he long been employed in that capacity?—He was employed, I think, last November in conjunction with Dr. Odling and Professor Abel.

4695. Is he paid by your company or by the companies generally?—I believe the professional men will receive the amounts and divide them, but I do not know exactly what the arrangement is. There is a general understanding upon the subject.

4696. He is professionally employed by several companies for the purpose of making those analyses?—Yes.

4697. And he is so employed now?—I think his employment has ceased. He has given evidence before the committee of the House of Commons.

4698. You, I think, are in some doubt as to the application of the principle of constant supply, and you referred to some experiments that you made in Westminster?—Yes.

4699. Do you think that under proper regulations, with ample authority of inspection and control, it would be impossible to apply that system?—There are such difficulties attending it, and I hear of them on all hands, that I think it is not only a large experiment to introduce, but it would require an amount of interference almost greater, I think, than we should carry out in the metropolis. Recently I have heard of the supply at New York having failed through the waste of water, and I have also recently received reports from the city of Boston upon the same subject, from which I have taken some extracts which will show the difficulties that they have had to contend with there. The New York cases are something of the same sort, but they seem to have gone to an extent of severity almost that we should not admit of.

4700. Did that failure of supply in Boston occur during the time of the war between the northern and the southern States?—No, it is spread over several years; it goes from 1859 to 1865, and it seems that between January the 1st, 1865, and May 1st, 1866, the number of notices issued for leaks was 9,555, and the number of persons fined for waste was 3,093. They were wasting one-half of the water; then it had this bad effect that the inhabitants of the higher parts of the town could not get any water at all, because the lower parts used it, and they persisted in throwing water over the streets, although they were actually starving in the upper parts of the town.

J. Simpson, Esq.

5 June 1867.

These are notes extracted from the reports of those different years, which I beg leave to hand in.

The witness delivered in the following paper:

MEMORANDA as to the WASTE of WATER under constant Supply at BOSTON, U.S., from 1859 to 1865 inclusive. Extracted from the ANNUAL REPORTS of the WATER BOARD to the CITY COUNCIL.

REPORT FOR YEAR 1859.

Page 31. Daily consumption 13,175,000 gallons against 12,847,000 gallons previous year.

In 1858 consumption 72¼ gallons per head, estimating population at 178,000.

In 1859, if population taken at 183,000, consumption 72 gallons per head, scarcely varying from that of 1857 and 1858.

"It seems as if we might now fairly conclude that the individual consumption had come to its maximum, the variation in three years not exceeding one gallon."

Meters applied more numerously than in previous years, and proposed to be used still more extensively.

Appendix page 4. Waste water from lake over dam into Sudbury river in the year 7,569,000,000 gallons.

REPORT FOR 1860.

Pages 6 and 7. "Consumption of water.—In the last annual report the following language was indulged in: It seems as if we might now fairly conclude that the individual consumption had come to its maximum, the variation in three years not exceeding one gallon, say 72½ to 73 gallons, but the present year is a fearful example of the fallacy of such calculating. By the report of the engineer it appears that the average daily consumption of water has been 17,238,000 gallons. By the census returns it appears that the number of inhabitants is 177,902. This shows a consumption of 97 gallons for each individual, an amount believed to be without parallel in the civilized world. Of course there is nothing in the sales of the water that could lead to the expectation of such a monstrous increase, and we must again resort to the old story of extravagant and inordinate waste."

Lake never full to height of dams during year, so that whole available supply drawn, although rainfall 55½ inches against average of 48¾ inches.

With a rainfall of 55½ inches the maximum yield of this lake will be 17,700,000 gallons, but as average only 48¾ inches a proportional diminished supply can only be safely relied on.

Page 8 Capacity of aqueduct put to severest test that ought to be applied, and to work it under any increased head must be attended with the utmost hazard.

Conclusions:

1st. That the lake cannot be relied on for any greater supply of water.

2nd. That the aqueduct can convey no more water than it has done this year.

"These conclusions are of a nature to arrest public attention and to induce inquiry. What is to be done? What use shall we make of the present quantity, in view of the great difficulty and expense of increase? Every effort

Page 9. should be made to guard against *waste*. . . . When all the unnecessary uses of the water are stopped, then, in case of insufficient quantity, it would become the policy of the city to cut off, one after another, the classes of takers for mechanical purposes. It is to be hoped, however, that the time is not near at hand when this will be necessary; it is only alluded to as indicating what would undoubtedly become the policy of the city at all times, in order to supply a full and needful quantity of pure water for domestic purposes. Meters continued to give satisfaction and would be more extensively used."

REPORT FOR 1861.

Page 9. Dam at outlet of lake raised and further supply from a pond brought into lake.

"With this addition to the source of supply there ought to be water enough for the city without any additional expense, and the Board are confident there would be were it not for the wasteful use of the water in the city. This has been a topic of discussion in the various water reports for several years. The present Board have adopted energetic measures by the aid of the police in preventing this evil, and these measures have been attended with marked success. At the same time the only efficient remedy must be found in the citizens themselves in the use of water, and in giving information of any wasteful use by others, or by the general adoption throughout the of water meters, and an entire change in the assessment and collection of water rates."

Some methods of using water highly objectionable; hopper closets for instance. No water to be supplied to hopper closets made after 1st January 1862. Pa

Most satisfactory method of charging water would be by actual measurement; but practical difficulties against introduction of meters over the whole city, and plan would require expenditure of half a million dollars for meters. Pa

Average daily consumption 18, 189, 300 gallons being 951,000 gallons in excess of previous year. Pa

On the 1st January 1862 water in lake 7 feet 11 inches below high-water mark leaving only 2 feet 1 inch above low-water mark. Pa

As consumption of water increased so fast, and lake supply would very soon be all used, engineer recommended survey to be made to determine a new source. Pa

REPORT FOR 1862.

Average daily consumption 16,600,000 gallons being 1,589,300 less than in 1861. Saving mainly owing to meters being placed in establishments where large quantities of water used. Pa

Surplus water from lake into river during year 33,200,000 gallons equal to about two days' supply. Pa

Quantity used equal to annual average rainfall, and all that lake can be relied on to furnish annually.

More storage room needeed, as well as a new source of supply.

REPORT FOR 1863.

254 meters in action. Their use, where large quantities of water consumed, proved to be very satisfactory; in places where large numbers of hands employed, a great deal of water wasted, but when proprietors obliged to pay for it by the gallon they find it for their interest to do what they can to prevent this waste. Pag

Average daily consumption 16,238,500 gallons. Pag

REPORT FOR 1864.

"Waste of water. This subject, which has been brought to the notice of the City Council in the annual reports of this Board for many years has been and will continue to be a source of great anxiety, and one that will require active measures to prevent. The last two months the lake was at such a low point that the Board believed it to be their imperative duty to use every means in their power to put a stop to the enormous waste which they felt sure was taking, and they commenced by issuing a circular to the citizens, calling their attention to the fact. This had a very good and marked effect, but still a great waste continued, and as the lake was still falling a second notice was issued, and persons having house hose were requested to discontinue its use; and it was also decided to employ a suitable number of persons to examine all the water fixtures throughout the city, and report each day to the office any waste that might be discovered, and also all leaks. This was immediately carried out by the water registrar, and the result has proved that nearly one-half of the water that has been brought into the city has been wasted. For the first ten days, which included about one-third of the city, there were reported 531 cases where water was running to waste, and 1,353 cases where fixtures were out of order and water was leaking on that account. Pag

"We have no doubt whatever but that the supply of water is simple for years to come if used in a liberal and proper manner.

"The active measures which the Board has adopted have already greatly reduced the consumption, or we should say waste of water, and our reservoirs are now nearly full. According to the estimate of the engineer the average amount of water brought into the city daily is 16,681,000 gallons; to bring this enormous quantity we have been obliged to run our conduit to its utmost capacity, and thereby endangering the works; and as we know that a large part of this is wasted, we shall continue to use every means in our power to find out and prevent the same." Page

312 meters in use—Nothing but their great cost prevents their application to all consumers, as the only sure way to prevent a continual waste, as consumers give their fixtures more attention when they are paying for any leakage.

20 men employed by Registrar to examine and report all places were water fixtures out of order and water found running to waste. Page

Daily consumption in November and December about 2,000,000 gallons less than corresponding month last year, owing to increased vigilance and care on the part of citizens inspired by fears of short supply, and by the extra exertions of the Board and it officers in tracing out sources of waste. Page

REPORT FOR 1865.

"Unless we are favoured with copious rains during the summer and fall, it will require the strictest economy to keep up the supply of water throughout the year, without the doubtful and expensive expedient of raising it by artificial means to the level of the conduit. By the tables of the engineer it appears that the rainfall for 1865 was the average of the last ten years. Yet there was during the last year, and is now, a very general complaint in the neighbouring towns of the scarcity of water, and much inconvenience, if not sickness, has been consequent upon it."

"The constant supply with which our inhabitants have been blessed should always be kept in mind, and the efforts of the Water Board *continue* to be seconded by all good citizens, not only by preventing waste upon their own premises, but by giving prompt notice of waste by others. The apprehension of a short supply will necessitate the greatest watchfulness on our part; and if it is found necessary to subject the takers to some slight inconvenience from the visits of the inspectors it must be borne with patience as it is only in this way we can detect the improvident and wasteful."

"The number of notices issued for leaks from January 1st 1865 to May 1st 1866 9,555."

"Number of persons fined for waste - - 3,093."

Hopper closets increased in number to 8,000, and consumption of water found to be many times in excess of ordinary pan closets. These closets, with *improper fixtures*, are one cause of excessive use or waste.

"Board contemplate appointment of two or more officers, whose duty it will be upon an alarm of fire, to assist in opening the hydrants, and to see that they are properly closed after the hosemen have left; to visit the hydrants used for supplying the steamboats with water for cleansing decks and other purposes; and to have a general supervision of all hydrants so far as to prevent improper use. It will be desirable that these officers have police powers. In other cities a large number of such officers are advantageously employed."

Average daily consumption for domestic purposes, found by actual experiment to be $24\frac{2}{10}$ gallons per head.

"The number of meters has been largely increased. If it were not for their high cost (about 50 dollars each) it would be desirable to deliver all the water by measure, and then each taker would pay for what he consumed. If such a system could be adopted, the quantity of water drawn from the lake would be reduced nearly, if not quite, one third."

"However desirable this may be it cannot be accomplished at present, for we have failed as yet to find a cheap reliable meter. The whole number of takers is 27,489, and much the largest proportion pass less than ten dollars a year. Consequently the expense at present cost would nearly consume the income."

Price of water by meter settled at uniform rate of three cents. per 100 gallons = 1*s.* 3*d.* per 1,000 gallons.

Consumption of water for 1865 reduced 25 per cent. as compared with consumption of 1864; one consequence of this economy was that the citizens who resided upon the higher grades were accommodated with a more regular and abundant supply of water than for some years past.

Daily average supply in year, 12,662,000 gallons.

Waste in night: average 282,000 gallons per hour or 6,768,000 gallons per day.

Maximum consumption per day, 18,000,000 gallons.

4701. Are you acquainted with the water supply of Hull?—Yes.

4702. Do you know that they have the constant system in operation there for a large part of the town at all events?—They have, but in the upper parts they overcome the difficulty by having cisterns. I would say that in London I do not believe the difficulty will ever be overcome without cisterns.

4703. The engineer of the Hull Waterworks has given evidence before this Commission to the effect that they have the constant system in operation in a large portion of the town, and that they are adapting the other part of the town to receive the constant pressure, and that the result of the application of that system has been a saving of 25 per cent. in the consumption of water. Would that be in accordance with your views?—I do not think that the one system would involve any more water than the other as far as my experience goes.

4704. Is not the liability to waste the principal objection to the constant system?—It is, but when it can be properly controlled I do not believe there need be any more water wasted under that system than under the intermittent system.

4705. Then what would be the difficulty?—Getting into the houses to stop the waste.

4706. Would not the people of London become used to that kind of control, just as the people of Hull have become accustomed to it?—I do not know, you would experience great difficulty in getting into the houses in London. I have had notice frequently myself of attempts at robbery by persons attempting to get into houses by false personification, and the inhabitants will not allow the turncocks to go into the houses.

4707. (*Sir B. Phillips.*) The better class of houses have in effect a constant supply, have they not?—They have.

4708. Consequently the only difficulty is with reference to the poorer tenements?—Yes, I know it is stated that in many towns the constant supply is carried out, but I do not think we get at all the difficulties connected with it. I will take Cambridge as an instance, they have carried the system out there to a certain extent, and they have succeeded, but they have had very great difficulty. In the case of one of the colleges there were 10,000 gallons wasted, when the quantity required was not 1,000 gallons, and in their Act of Parliament they have got a clause that the water to be supplied need not be constantly laid on under pressure, that is the instance of one town. Folkestone is another, where they used every drop of water out of the reservoir and they were compelled to come to Parliament to get clauses which restricted to four hours in the morning and four hours in the afternoon; and in Bristol also the waste was so great that they came for power to shut off the supply every night, and they have power to do so by a special clause.

4709. You have had great experience of course in the management of all classes of property in supplying them with water. Has any system occurred to your mind which would enable you to give a constant supply to the poor, in a court for example where there are 20 or 30 houses?—One mode which occurred to me was to put up a cistern and allow the inhabitants to have water to draw off constantly, or to put up a sunk tank and put a pump up for them—that would be another way; or another way would be to let the water go direct from the mains and let them draw constantly; but then that must be coupled with some means of compelling them to pay, because when we talk of the poor it is difficult to conceive in this metropolis any poor but those who are really in the workhouse; you must define what poor people are. A great deal of that small property is in the hands of agents, and they would do anything to make a penny or save a penny, and they have very great difficulty in collecting the rents. In the case which I mentioned in Westminster, they would not pay the rent, and they let their tenants go to the adjoining courts for water, and they said that they had a right to the water.

4710. But you have the power to go upon the owner, have you not, to pay for the water?—Yes, but it is a very difficult thing; perhaps he lives in Paris, and you have a difficulty to find out where his agent is, and they play all sorts of tricks.

4711. Cannot you take the house?—No, we have not the power to go to that extent. And in many of those poor houses the chairs and benches are actually chained to the floor.

4712. I suppose the great difficulty really is in substituting something for those filthy receptacles which they have now?—That is so. It is done in the new lodging houses. Miss Burdett Coutts has some houses in Westminster, and the principle of constant supply is carried out in them, and they take about $7\frac{1}{4}$ gallons a day, each individual. To some extent no doubt there is a difference there, because the people are not at home to consume the water all day long, but that is the result of measuring the water into their receptacles, and they have to all intents and

J. Simpson, Esq.

5 June 1867.

purposes a constant supply, for it is on about eight hours a day.

4713. Have they iron tanks to hold it?—Yes, ordinary tanks.

4714. (*Col. Harness.*) How is it measured into those receptacles?—It is measured by a meter which we have introduced of late years on the principle of Barker's mill; by putting centrifugal vanes to counteract the force of the water, we are enabled to measure very accurately within one gallon. It is a very beautiful application, and it is comparatively novel. I believe in Chelsea we have water to the amount of about 7,000*l.* a year sold in that way, and in Lambeth about 5,000*l.*

4715. (*Sir J. Thwaites.*) What is the charge for water per 1,000 gallons?—It is according to a scale, from 6*d.* to 9*d.* and 1*s.*

4716. Does the difference of charge depend upon the quantity?—Yes.

4717. (*Col. Harness.*) I suppose the rotation of the arm is checked by the vane?—Yes, by putting two vanes in and filing them according to the size, that counteracts the centrifugal force, and we are enabled to bring them to measure gallons, but to apply it generally it is an expensive thing; you could not do it for small houses, it can only be applied to a number of houses, otherwise the thing would amount to the cost of the water, and more than that. In the case of the American houses that I have referred to, they would like to apply this principle, but they state that the expense is against them.

4718. (*Mr. Harrison.*) In your experience, what should you consider, looking forward to a few years to come, to be a sufficient provision per head for the population of London, including all public services?—About 30 gallons would be my guide. We used to stop at 20 gallons, but as the inhabitants have got access to water with greater facility, they have increased the use of it; there is no question that the facility of obtaining water increases the use of it.

4719. You do not think it would be necessary in making a calculation to go beyond 30 gallons per head?—That would be quite the very outside for all purposes.

4720. (*Sir J. Thwaites.*) Including manufactories?—Yes.

4721. (*Mr. Harrison.*) Taking it that you can get 200,000,000 gallons from the Thames proper in case of necessity, and say 60,000,000 gallons from the Lea, with the power which they state they could get by additional provision, that at 30 gallons per head would be equivalent to a provision for 8,700,000 people?—Yes, in fact, it would be equivalent to the supply of a number of people which I can hardly imagine ever could be massed together.

4722. Practically, therefore, the Thames might be looked forward to as being able to supply London beyond any possible increase?—I think so.

4723. With regard to the Aberdeen waterworks of which you are the engineer, that would be a soft water, would it not?—Yes, very soft, and there is this difficulty with it, that it acts very powerfully on the pipes, and I apprehend that with all that class of water you would have the same thing occur.

4724. Are the pipes made of lead?—Yes, and iron pipes also. In Aberdeen this action goes to the extent of stopping the pipes up, and they are regularly fouled, but the Aberdeen water is a very beautiful water. Also I may say that that is a peculiar case, because we have no reservoirs for storing the water in Aberdeen. We take it direct from the river and we filter it, and it is delivered into the service reservoir near the town.

4725. (*Sir J. Thwaites.*) That is granite water, is it not?—It can hardly be said to be granite water; the under formation is granite of course, but the water comes from a very large moor district, although we have taken the water from a part above where the moor streams come into the river.

4726. Is there any peaty-colouring matter in it?—A very slight amount.

4727. (*Mr. Harrison.*) Supposing you had within reach of London water similar to the Aberdeen supply, and you had the present Thames water, should you give any decided preference to the one over the other?—No.

4728. You would not look to it as being a great object to obtain a soft water for London?—No, it would be rather a question of expense than otherwise.

4729. Supposing you had them at the same cost, what would you say?—It is a question which is one of choice. But the case of the Aberdeen water does not apply, because there our least flowing stream is about 150,000,000 gallons, and we only want 6,000,000. But there is a very great difficulty, as I would point out to the Commissioners, in obtaining the requisite quantity of water in dry seasons from all those northern districts. The case of the Liverpool waterworks was an actual failure. They went to a place called Rivington Pike, in the direction of Bolton, where there is very good rainfall, but instead of getting 15,000,000 gallons a day, the supply came down to 6,000,000.

4729*a*. Dr. Letheby, in the evidence which he gave before this Commission, stated that if he had a soft water such as you have at Aberdeen at the same distance, and to be attained at the same cost as the present water supplied to London, he should prefer chalk water to soft; do you coincide with him in that opinion?—I do not know that I should not be of the same opinion. I can only say that I have understood recently—I have not seen the French engineer who is in charge of the works at Paris, but I understand they have come to the conclusion to go for water to a district which I know is limestone.

4730. I have no doubt that you, in investigating every matter connected with water, have paid some attention to the reports of the French upon their water supply?—Yes, I have seen them.

4731. Could you give the Commission some facts that may have occurred to your mind in connexion with those reports?—I have seen the reports, and I know that the preference was stated very strongly, after a very long investigation, for waters out of a limestone district. I believe the water is a much better keeping water than it is from the other districts where they could have obtained soft water.

4732. Did they carry their investigation as to the effect of the water upon the men in their army?—I believe they did, and they made out that they had the finest men from the hard water districts.

4733. Do you anticipate a great improvement in the quality of the water of the Thames from the Act of last session?—I do. It is very much improved since the time we went up to our present source. If you remember 15 years ago we were pumping from Waterloo Bridge, and our going to Hampton was a great step in the direction of improving the quality of the water supplied to London. In fact, altogether it is a different system that we are pursuing now. Formerly we never filtered the water, we did not even subside it, but latterly we have been compelled to do it, and not only the water for drinking, but we find that economy is on the side of our filtering the whole of it; we have only one apparatus or system and we can do it as cheaply as we could separate the one supply from the other.

4734. (*Sir J. Thwaites.*) Is yours a sand filter?—Yes. I have tried many experiments in filtering and I have always doubted the propriety of using water that required any other filter.

4735. (*Mr. Harrison.*) Your attention no doubt has been directed to the question of the possibility of separating the water for household purposes from that supplied for other purposes?—Yes, and from personal experience I would rather not have that done. I have had it separated in my own house, that is to say, I refilter the water. The water in my house is brought over the sinks, and it is a continual cause of contention that the water is not bright, and that it has not been drawn from the filtered water cock, so that I am

very sorry that I ever introduced it. One system of water supply in a house is quite enough. In fact, servants will not go to the proper taps at all times; they use that which is nearest to them, although the other may be only a few inches further away.

4736. My question had reference to that which is used for flushing sewers and street purposes, whether it would not be practicable to separate the waters in the case of supply of large towns?—It would be, and I confess it is my idea that it might be carried out in the metropolis, although it is a question whether it is worth while, and there are some circumstances connected with it which should be taken into account at the time when it is considered. In the Chelsea company's district when we were pressed for filtered water we found very great difficulty in supplying a higher service at the time when we were supplying water for the roads, and for flushing the sewers; and we laid down separate pipes, and we have them now, and we do not filter the water for the roads. The only thing against it is the difficulty of keeping the pipes in order, as they would only be used during a portion of the year, practically only during six months of the year.

4737. (*Col. Harness.*) And there would be very few points of delivery?—Yes, and that is what has often struck me when I have heard allusions made to a separate supply for the metropolis in case of fire. How is the service to be kept in order? The only reason in my opinion why our works succeed is that they are constantly in use, and anything happening to them very soon becomes known, whereas if you have part of your system of pipage not in actual use you will find great difficulty in keeping it in order. You will be surprised to hear that with pipes not much used, in the course of a fortnight or three weeks, the purest water at this season of the year becomes quite putrid, and smells dreadfully, and, I believe, that the whole of the pipes, under such circumstances, would be liable to be stopped with black oxide in all the ends of them.

4738. (*Mr. Harrison.*) We have had evidence that it was desirable to supply London with drinking water by a separate service altogether, but that would scarcely be your view of the matter?—If the Londoners would go to the expense of probably a million and a half or two millions of money, or it might cost even more than that, and all the troubles and complications which would be sure to arise, it might be very desirable, but then the question is, whether really pure water is required to an extent beyond which we can get it by filtering it privately. A great deal of what people would call well water is very bad water, even in the country districts, and well water in this metropolis is as bad as it possibly can be, most foul and filthy stuff, and no doubt cholera has been traced to the use of that water. The water immediately below the plastic clay is not a pure water, it absolutely contains double the quantity of organic matter which our river Thames does, and although it is a soft water its softness is due to its containing a large portion of carbonate of soda, which when used for locomotive engines forms an effervescing mixture and renders them liable to explode.

4739. Is there any public officer now attached to the Registrar General's Office who has the power of reporting upon the analyses of the waters of the different water companies?—Dr. Frankland does report upon them. The Registrar General has requested the companies to send him accounts of the quantity of water supplied monthly, and we have done so, but we do not know anything more about it than what appears in the Registrar General's reports.

4740. You are not aware whether there is any public officer whose duty it is to analyse the waters of the companies from time to time, and report upon them?—No more than that Dr. Frankland does report upon them, and I presume that he does communicate with the Registrar General; at all events, we see the analyses in the monthly reports.

4741. If the population increased to double its present amount, the water would be supplied, would it not, in a totally different district from that where it is now supplied?—It would.

4742. Therefore the question of distribution would be only extending the distribution over a larger area?—Yes; a great deal of it would come into districts which are surrounded by houses in the present districts. For instance, there is Chelsea Park, which I suppose contains about 40 acres, with 800 or 1,000 houses, and patches of houses in that way would be in the existing districts, but London is extending in the suburbs to an immense extent.

4743. But you do not anticipate any great physical difficulty in the distribution of the water to all those districts when it is required?—I think we have overcome all that. We have taken it over the Surrey hills to every place where it is required, that is to say, between Kingston, and Norwood, and Croydon, and Beckenham, and London.

4744. Do you think it would be desirable by any Public Act to compel the water companies on the one hand to supply water to the poor, so that they may have a sufficient supply, and on the other hand to compel the owners of poor houses to pay the water companies for that supply?—I think it would be a very good thing to do something in that direction, but I do not quite see how the companies could do it, because there is a difficulty in knowing who the owners of the property are. A man might perhaps have half a dozen houses, and put them in one man's hands to collect the rents and manage the property, and there is very great difficulty in knowing who to go upon to get paid.

4745. Excepting the question of the difficulty of collecting the water rents, you do not see any objection to the principle?—No; at the same time something should be done to compel them to maintain in a proper state the cistern and fittings, and everything that is connected with the supply, for really the great difficulty in the metropolis now is in affording to the poor sufficient receptacles for water, not only in size but in number. They allow too many to resort to the same place, and they have quite a fight for water now.

4746. (*Sir B. Phillips.*) You would have stand-cocks in courts and alleys also?—Yes, only you must have a sufficient number of them; if you get more than 10 houses to a stand-cock, you will find them not sufficient, because the poor people resort to them immediately they come home from their work in the afternoon about 6 or 7 o'clock; that is the principal time when the water is drawn in those districts. There is a difficulty in dealing with that question at present, and that is to induce the persons interested in property to act in any way which involves expense. Unfortunately in some cases the vestrymen are large owners of property and they will not initiate anything, nor will they follow up anything.

4747. (*Mr. Harrison.*) My assumption was that a Public Act might be passed, making it compulsory upon the owners to pay for the supply for the poor people?—That is very good so far as it goes, but we want something more; we want the persons who let their houses to do what once I mentioned in a Committee of the House of Lords, but which was not received with great favour. I said that I would render it illegal to let a house without good drainage and a good supply of water, and that an Act passed in that way would settle the whole question, because then they could not collect the rents at all without complying with the provisions of the Act.

4748. (*Sir J. Thwaites.*) You are probably aware that the principle now adopted with regard to the Reform Bill is to abolish the compounding system, and that the practical effect will be to exclude parties who are now qualified for serving on vestries on their compounded property from those vestries?—I have understood so; I should be very sorry to enter into individual cases, but for the last 40 years I have met with the difficulty time after time, and up to the present moment it is not got rid of. There is one district now with which we are in contention, and I find that it is solely because the parties behind the

J. Simpson, Esq.

5 June 1867.

scenes are interested in the property, and they will not give a penny to improve the supply of water; in fact they are not the right owners at all, to the extent of 50 or 60 houses.

4749. (*Mr. Harrison.*) Do you not know that there is power given to boards of health to close up all houses that are not in a proper state for habitation?—Yes.

4750. Why should not the question of a proper supply of water be equally a question for their decision?—I do not know of anything which should take it out of that category. The fact is the matter wants attending to as much as anything I know, but we have to deal with a class of property to which the owner will not do anything.

4751. (*Mr. Prestwich.*) You spoke of the iron pipes of the Aberdeen water supply getting stopped; how long had they been in use?—I believe about 20 years.

4752. Are you speaking of the new supply or the old supply?—The old supply. The difference between the old and new supply was that one was about 25 miles by the course of the stream down the river where they pumped it, and in the new supply I have taken it at a higher level, so that it does not require pumping. Consequently we have got the water from a purer stream, and we have avoided the moss water locks and streams by going up there.

4753. Have the pipes had to be renewed during that period of 20 years?—In some cases they have been taken up and cleaned out. The manager has been in the habit latterly of coating them with bitumen to prevent the action of the water upon the pipes.

4754. Has that been effectual?—To some extent I believe it has, but I have no faith in it as a constant thing. I think it very likely that the water will make its way underneath the preparation, and then the oxidization will go on as usual.

4755. How long has that coating preparation been under trial?—About ten or twelve years.

4756. In the many towns with the water supply of which you have been connected, Aberdeen and the others which you have mentioned, have you had any cause to see that there was preference to be given to the very soft water of Aberdeen or Glasgow or to the moderately hard water of other towns?—No; apart from their organic impurities, I certainly have not. I know that in many cases where the water has been extremely soft, in the case of Glasgow itself, for instance, they were very apprehensive about the action of the water on the leaden pipes producing carbonate of lead and having the effect in many instances of producing painters colic, of which I have seen cases.

4757. Has the result been such as was feared?—But I believe the real fact of the Glasgow present water is that it contains a slight quantity of sulphate of lime, and however small it may be it is a protection. Many years ago Professor Brande, who was analysing water for me, stated this to be his opinion, and I found it to be the case from practice, that wherever sulphate of lime was present in the water a luting or protective surface formed on the pipes internally, and effectually protected them, and we could use leaden pipes with impunity; but when it was absent from the water, and when free carbonic acid was in the water, we had a difficulty in dealing with the leaden pipes. In the case of the dog kennel at Windsor and of the French royal family at Claremont, there were notorious instances in which the dogs were poisoned by the water. Owing to the water being extremely soft water and containing a certain portion of free carbonic acid, the dogs in the kennel at both places suffered from paralysis of the feet.

4758. The water of Loch Katrine does not show the presence or any trace of sulphate of lime does it?—If there were only a trace of it it would be sufficient.

4759. When you give the quantity of water per head of 34 gallons as being sufficient, that is including all the waste which at present occurs?—That is including everything.

4760. Might not that quantity be reduced providing that the large amount of waste which now takes place could be obviated?—No doubt of it, although the habits of people have very much changed in the last few years, and they use more water generally for all purposes than they did formerly.

4761. The quantity taken from the Thames is at present 50,000,000, but looking to the increase of the population and the future wants of the city, to supply which probably 150,000,000 or 200,000,000 gallons might be required to be taken, will not the question which you have before referred to, of filtering the whole of that water, or only such portions of it as might be required for drinking purposes, become a more important question from year to year to be considered, and whether a large portion of the water for sewers and house purposes might not be supplied apart from the water required for drinking?—That may be so, but you may take this that filtration may be carried on to the extent of 150 gallons per house per diem for 4*s.* 6*d.* per annum, including interest of money and everything, so that it would be a very small sum to save for the purpose of having separate systems of supply.

4762. (*Sir J. Thwaites.*) Do you mean that that is the cost of filtration by the company?—Yes.

4763. Have you any idea, taking the population as a whole, what quantity of water is actually consumed for drinking purposes?—As far as my own observation goes, taking isolated houses, I should think about one fourth is used, say from five to seven gallons per diem for household use, for drinking and for food.

4764. I am speaking now of the quantity used for drinking?—It is a very small quantity, it would be difficult to say how much. I should think that a two-gallon bottle put on the sideboard in the morning would keep the house going the whole day.

4765. (*Mr. Prestwich.*) Are you acquainted with any gaugings of the Severn in the upper part of its course?—No, I am not. There were very elaborate gaugings taken some years ago by the resident engineer to the Commissioners, and sections the whole way down the stream.

4766. Do you find the flow of the Severn more irregular than that of the Thames?—I think it is.

4767. It contains a much larger volume, does it not?—No; a much smaller volume.

4768. Is it your opinion that the quantity of spring water flowing into the Thames maintains a larger uniform flow?—Yes, very much so. The very strata itself has that effect. In the Oxford canal they have a great quantity of water from springs in its bed in the neighbourhood of Cirencester. In point of fact their mode of supplying the canal is the reverse of what is the case with ordinary canals, for instead of having reservoirs above ground they have them under ground.

4769. (*Mr. Harrison.*) I think the Commission have had it in evidence that the summer flow of the Severn at Tewkesbury does not exceed 90,000,000 gallons a day; are you acquainted with that fact?—I daresay it is so; it is very small in comparison with the Thames. I should doubt whether it is even that, and there is an opportunity of measuring it there which there is not in the Thames. I have seen the water very low in the Severn up there.

4770. (*Mr. Prestwich.*) You have no doubt seen the estimate which has been made in Mr. Bateman's pamphlet with regard to the cost of his scheme; have you paid attention to that calculation of Mr. Bateman's?—Yes, I have.

4771. It would appear from calculations that after incurring the expense which would be necessary for carrying out the larger works a domestic rate of 10*d.* in the pound would be sufficient to be levied. At present the rates of the water companies vary from 10*d.* to 1*s.*?—Yes.

4772. If the supply now delivered by the companies were put upon the same footing as that upon which Mr. Bateman and Mr. Hemans based their plans, that is to say if a certain quantity of water be allowed for public use and a compulsory rate or a certain rental valuation of the metropolis, it would

seem to me that the conditions are not upon the same basis; have you ever looked at it in that point of view?—Where the public supply has been introduced in that way, in the case of Manchester, they rate the warehouse property, but we have nothing of the kind in London. I believe that the rate at Manchester is 9*d.* on the house property and 3*d.* on the warehouse property. *J. Simpson, Esq.* 5 June 1867.

4773. (*Sir J. Thwaites.*) But you have a scale operating on the rent?—Yes.

The witness withdrew.

Adjourned to to-morrow at 11 o'clock.

Thursday, 6th June 1867.

PRESENT:

SIR JOHN THWAITES IN THE CHAIR.

Colonel HARNESS.
Alderman Sir BENJAMIN PHILLIPS.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

SAMUEL FURNESS HOLMES, Esq., examined.

4774. (*Chairman.*) Are you the borough surveyor of Sheffield?—I am. *S. F. Holmes, Esq.* 6 June 1867.

4775. How long have you held that appointment?—Since the Local Government Act was adopted in the borough, now nearly three years ago, but I held the office of Surveyor to the Board of Highways for important districts in the town for 15 or 16 years previous to that.

4776. Have you adopted the Local Government Act in Sheffield?—We have.

4777. Have you not a corporation at Sheffield?—Yes, we have a mayor and corporation. The town was incorporated in 1843, but they did not take the management of the highways.

4778. But you were incorporated in 1843?—Yes; but we had a Local Act for lighting and cleansing the town, which continued in operation until the adoption of the Local Government Act.

4779. Do you know any other municipality in the country that has adopted the Local Government Act?—Yes, many.

4780. I should have thought that your powers would have been quite sufficient without that?—For the management of the highways they were not.

4781. However you have held the office of surveyor to the municipal authorities under the mayor and corporation under the Health of Towns Act?—Yes, I have.

4782. Since your appointment have you had your attention turned to the subject of the water supply?—We have had our attention particularly turned to it since the unfortunate catastrophe of 1864 when the Dale dyke reservoir burst; since that period the town has watched earnestly the condition of the water supply of Sheffield. Previous to that the water supply had gone on regularly; and we had no cause of complaint. The town has no control over the water or the gas.

4783. What was the source of the supply prior to the bursting of that reservoir?—From storage reservoirs on the watersheds of the rivers Rivelin and Loxley.

4784. And that reservoir which burst was in point of fact one of the receptacles of the water from that gathering area?—Yes.

4785. The new works are not completed are they?—No. The water company's acts have been in existence in Sheffield for a great number of years. I should think for more than half a century, but under the Act obtained in 1853 they obtained further powers, and under the powers of that Act they were constructing the Dale dyke reservoir. It was completed, and they had just filled the reservoir, when on the first night of its being filled it burst and inundated a great portion of the town of Sheffield.

4786. What is the extent of your gathering ground?—The water company have obtained further powers during the present Session of Parliament, the Act for which has received the Royal assent.

4787. Is it a joint stock company which is now supplying water, or is it in the hands of the municipality?—It is in the hands of a joint stock company.

4788. Can you tell us the extent of the gathering ground?—The extent of the gathering ground is about 34½ square miles.

4789. Has it been increased since the accident?—That is the gathering ground which the company have authority to take water from at the present time; it was about 20 square miles; it has been increased since that catastrophe, and is now about 34½ square miles.

4790. Can you tell us the rainfall due to that area?—The average rainfall of 10 years is about 39 inches.

4791. Is that the average of how many gauges?—It is the average of three or four gauges on different parts of the watershed; it is the average of the gauge on the river Rivelin. There is about the same rainfall on that shed as there is over the whole of the 34½ miles.

4792. You say that you have three other gauges?—Yes, there are three other gauges; but there has not been a sufficient number of years yet to get an average that would be a correct average.

4793. How many years have those been down?—I think some three or four years.

4794. What is the result of those three or four years?—I am not in a position to be able to tell that.

4795. Before you have assumed a rainfall of 39 inches, how much do you think, by making allowance for absorbtion and evaporation, would be available for the supply of water?—The amount actually collected in the driest years that have been known of late, that is, the two years 1864 and 1865, on the Rivelin was 20 inches.

4796. Do you mean collected or delivered into the river?—Collected into the reservoir; 39 inches did not fall in those years; in 1864 there only fell 31·880.

4797. Did you secure 20 inches out of that?—Yes; that was in the year 1864.

4798. Have you any other year that you can give us the net result of?—In 1864 and 1865; the evidence given by the engineer as to the amount actually collected, which is undisputed, was 20 inches in the two years for each year, the actual rainfall in 1864 was as I before stated, and in 1865 it was 32·470.

4799. When the rainfall was 39 inches you collected 20 inches, and when it was 32 you collected 20?—When it was 31·880 we collected 20.

4800. How do you account for the difference?—The difference as between 31·880 and 32·470 is not large.

4801. But you gave me 39 inches as the average?—Yes, 20 inches over the 34½ square miles would give, in round numbers, 27,000,000 gallons per day. Out of that they have to supply to the millowners as compensation about 12,000,000 gallons per day, leaving 15,000,000 gallons per day for the supply of the town.

S. F. Holmes, Esq.

6 June 1867.

4802. Is that sufficient for the supply of the town of Sheffield?—The town of Sheffield which is at present supplied has about 210,000 inhabitants, and the 15,000,000 gallons a day would give 25 gallons per head for a population of 600,000.

4803. What is the consumption of water now?—During the year when the average rainfall is anything like 39 inches they can give 12 hours' supply; but during 1864 and 1865 they were only able to give in the autumn of the year for some weeks three days per week, and that only for six or eight hours per day.

4804. When you say 12 hours, do you mean that the pressure is on for 12 hours?—Yes, the pressure is on for 12 hours.

4805. When you had a sufficiency of water was that 12 hours in the middle of the day, or when?—In some districts it varied from six in the morning to six at night, and from seven in the morning to seven at night in the other districts.

4806. That would give to each inhabitant how much?—About 11 gallons per head.

4807. Does that 11 gallons cover the water used for manufacturing purposes?—It does.

4808. Have you found that ample?—No; it is very deficient indeed.

4809. Do you mean for manufacturing purposes or for domestic use?—For both purposes.

4810. What, in your judgment, would be a sufficient supply, having regard to the town of Sheffield as a manufacturing town?—Having regard to the town of Sheffield consuming more water than most towns do for manufacturing purposes, I think we ought not to have less than 30 gallons per head for the population.

4811. There is a large consumption in the grinding trade, is there not?—There is a large consumption for engine power. In all branches of the Sheffield trade there is a great deal of engine power, and of course that consumes a considerable quantity of water.

4812. What is the quality of the water that you are now supplied with?—It is an excellent quality of water.

4813. Is it soft?—Yes, it is from the grit with overlying peat a portion of it, and from the black shale.

4814. Is it at all coloured with peaty matter?—It is until it has been stored in the reservoirs. We have large storage reservoirs, and from thence the water runs down a conduit for some miles to the services, and it remains in some of them for three days before it is used, and the colouring matter to a great extent is taken out.

4815. How long does it take to precipitate the colouring matter?—I should think two or three days would do it, but it is not often you can observe it in the town.

4816. I suppose in floods you get a larger portion?—It is in flood when you do observe it, you do not observe it in the winter season of the year.

4817. Have you any means of turning off the flood and storing the ordinary flow of the river?—In some of the reservoirs we have; in Dale Dyke reservoir unfortunately they had not taken the means of keeping the flood water out of the reservoir, it all had to come through the reservoir.

4818. Are you aware of the process they have now of allowing the water to drop and rush over in case of flood?—Yes, not allowing it to fall into the basin of the reservoir.

4819. You have no such means of separation?—No, we have not.

4820. Prior to this water supply how was Sheffield supplied with water?—Sheffield has always been supplied by a company, the present supply reservoirs which are close upon the town of Sheffield, from 150 feet above the lowest part of the town, were formerly the collecting reservoirs, and the moor and uncultivated land was closer to the town then and those reservoirs were made for storage on the hill sides.

4821. The town of Sheffield has for some time been supplied with the same water, although formerly it was taken at a lower point?—Just so.

4822. What is the effect upon the health of the inhabitants of using this soft water?—We consider that it has a very beneficial effect, our death rate now is very low, and we believe that to some extent is owing to the water.

4823. What do you call low?—About 21 per 1,000, that has been the average for some time.

4824. It has been over 30 has it not?—It has, we have very much improved in our death rate within the last few years.

4825. Do you attribute that to the supply of pure water, or to improved drainage or both?—I think to a great extent to improved drainage. I do not think so much is to be attributed to the water as to the drainage.

4826. How do you get rid of your drainage?—We have constructed a drainage system to carry it below the town, but unfortunately we are throwing it into the river. We introduced a plan two years ago to take it down below. Thorn, which would be some 30 miles below Sheffield, and we tried to induce the towns below in the basin of the Don, Doncaster, Barnsley, and other places in the same watershed to join us in applying for an Act of Parliament in order to take it to Thorn waste and utilize it, but we failed in getting any support. Consequently we have postponed that for the present or else we had a scheme for draining the whole watershed area of the Don into one large conduit, and then conveying the sewage to Thorne waste and there utilizing it.

4827. As to the gathering area have you realized your anticipations of the quantity of water that you would obtain from that 34½ square miles?—The amount actually collected in those two dry years which I think you will find throughout the country, were the driest years that have been known in this country for a great number of years, almost within the memory of man, was 20 inches on upwards of 5,000 acres of gathering ground bearing about the same elevation above the level of the sea as the whole of our gathering area does.

4828. How does the deficiency in quantity arise, is it because your storing power is not sufficient on the capacity of your conduit or what?—We had not sufficient gathering area previous to that. On the Rivelin watershed which I am particularly alluding to that 20 inches of rainfall being collected there we had actually more storage than in most years we could fill. We had more storage competent to the drainage area than is usual.

4829. I understand that you will have storage equal to the water due from 34½ square miles?—Yes, that is so, but that embraces not only the watershed of the Rivelin but the watershed of the Loxley and the Ewden.

4830. You stated, did you not, that you have a great defficiency of supply, therefore, that 34½ square miles is not sufficient for your purpose?—The new reservoirs are not yet constructed. We are actually only taking water now from about 5,000 acres.

4831. The 20 inches which you say has been stored applies to a limited area?—Yes, the area that we are now gathering from.

4832. But you are extending your area, how many square miles?—We are extending our area to 34½ square miles, from about 20 square miles.

4833. That is to say, you are now increasing it to 34½?—Yes.

4834. But how long will it be before your reservoirs are completed?—The latest period for completing the last of the reservoirs is fixed for 1877.

4835. Is that the time necessary for the structural works?—No, they are bound to give us a constant supply under the Act of 1864, that is to say, in 1853 the company bound themselves to give us a constant supply 10 years afterwards, that would have been in 1863. They completed their Dale Dike reservoir in the autumn of 1863, and proposed giving us a constant supply in 1864. Then the disaster happening they came to Parliament to ask for an extension of time for giving us a constant supply, and got their time increased to 1869. They are bound now under

their present Act to give us a constant supply in 1869, and are now constructing two reservoirs, the Strines Dike reservoir and the Agden reservoir; the latter reservoir will be completed in 1869.

4836. Then in 1869 the company will be in a position to give a constant supply?—Yes, if required by the town council.

4837. I suppose they then will be in a position to supply all the water that you require for both trade and domestic purposes?—Yes, they will.

4838. Up to that time, 1869, you will labour under your present difficulties of an insufficient supply?—Yes, if it were to be a dry year like 1864 or 1865 the consequences might be fearful to the town.

4839. The water from those 34½ miles will be more than sufficient, will it not, to supply all the town?—Yes, as I mentioned before it would supply 25 gallons per head to a population of 600,000.

4840. Is there any other town near Sheffield that could be supplied from the same source?—Yes, Rotherham could be supplied from the same source.

4841. Have the water companies power to supply any other town than Sheffield?—No, they have not.

4842. There would be no difficulty from the same gathering ground in supplying Rotherham also?—Not the least.

4843. What steps, if any, do you propose to take to supply the town with water until 1869. The water companies as I understand are relieved from their obligation under the Act of 1853?—Yes, the water companies are relieved from their obligation under the Act of 1853, but they are bound by a clause to give a constant supply in 1869 at the request of the town council.

4844. Is there any part of the town now under a constant supply?—No part of the town.

4845. As an engineer, do you see any difficulties in the application of the system of constant supply?—Not the slightest; it is all natural gravitation. We have got plenty of head for supplying the highest parts of the town.

4846. Do you see any advantage in substituting the constant supply for the intermittent system?—No, except in case of fire. There must be a great waste going on in the constant supply. There is waste in the day time and it is going on in the night as well.

4847. That would depend, would it not upon supervision?—To some extent it would, but in some parts every cottage house has a pipe and they turn the water on for every purpose.

4848. Has every cottage a pipe now in Sheffield?—A great number have obtained them during the last five or six years; a great number have stands in the yards; but that system is going out, nearly all the new cottages a e being erected with the water over the sink stone.

4849. From what I have observed they appear to flock round some standcock to take their supply?—Yes, they do.

4850. Then the houses are not provided with a tap and a separate service?—Until a few years ago the whole of the blocks of cottage houses were supplied with stands in the yards; but the houses erected since and even many of the older ones have had the water supplied in the houses direct in each case.

4851. Has that been under any order of the Board of Health?—No, it is simply the interest of the landlord.

4852. Have they not power to compel the proprietors of the houses to lay on a supply for the houses?—Yes, they have.

4853. And to charge the owner with the cost of the water?—Yes but the Local Board in this case has not the control of the water.

4854. But the Local Board of Health have power to compel the owners of property to apply to the water companies for laying on a supply to each house?—Yes, they have.

4855. And if necessary to charge the owner with the cost of supplying it?—Yes.

4856. Has that been the rule with your Local Board or have they neglected to put in force this power?—They have never had occasion to exercise this power. We have no cognizance of any cottages that are not supplied with water by stands or within their own residences.

4857. Will you state why it is that you now have houses supplied with a direct service, whereas some short time ago the occupiers were obliged to go to a stand-pipe to take their supply every day?—The land owners found it to their interest to do it; people prefer to take houses so. We have many working men in Sheffield, getting very good wages and they prefer to take houses with water in their own house without having to go to a common stand in the yard.

4858. Their self-interest has been sufficient to induce the landlords to adopt the improved system?—It has been so in many cases.

4859. What class of cistern is used generally?—We have a great many cisterns in the yards that are made of brick and cement, and those have a pump in them; they are made of 9-inch brickwork lined with cement and puddled behind.

4860. Those cisterns I presume are in the ground?—Yes, arched over.

4861. Then they insert a suction pipe into that cistern and give them a pump?—They do.

4862. Is that the rule?—It is adopted in 10*l.* 12*l.* and 15*l.* houses.

4863. For a 10*l.* or 12*l.* house, what size would the cistern be?—Various sizes; but there are many put down within my knowledge 9 feet by 4 feet deep, containing 146 cubic feet, which would be about 876 gallons.

4864. How often is the water turned on?—It is turned on every day except in those dry seasons to which we have been alluding.

4865. As a rule, how many inhabitants would occupy a house of 10*l.* a year?—The average in Sheffield is about the same as in most places, five per house, or rather under that.

4866. Then do you give a capacity of between 800 and 900 gallons to a house occupied by five persons?—No, there would be four or five houses to this pump; in those cases the pumps would be in the yard.

4867. The pump is in the yard, and there is inserted in that cistern a suction pipe or several pumps attached to a suction-pipe?—In many cases it is only one pump and they fetch the water from the pump in the yard to which they all have access, and there are other houses in which rather a better class of people live, but not so many of those houses into which several suction-pipes are placed and they draw it from them into each house; there are not many, but outside the town there are some few instances of that.

4868. You do not call that a separate service to each house do you?—It is taken from one common reservoir; that is supposing you have a yard behind a row of four houses.

4869. I understand that you have a block of houses and you form a reservoir or tank made of brick lined with cement to give between 800 and 900 gallons of water which is renewed every day, and that the occupiers of that block of houses, consisting of 6 or 10 houses, as the case may be, have a right in common to the pump or pumps which may be fixed?—Yes.

4870. That is not what we call a separate service to each house?—No; it is not a separate service to each house.

4871. Are there any houses in Sheffield of that class with a separate receptacle for water under the absolute control of the occupier of that single house?—Those that are supplied separately over the sink stone draw direct from the main; they have a tap over the sink where they would do their washing, and that tap is supplied in some instances direct from the main, so that when the water is not on, of course they cannot draw the water, and they have to store it from one time to the other.

4872. During 12 hours of the day, that is from 6 to 6 or from 7 to 7, they would have a constant supply?—Yes.

S. F. Holmes, Esq.

6 June 1867.

4873. It would be constant pressure?—Yes, a constant pressure.

4874. The pressure is simply taken off during the night?—Yes. There are other houses of a larger class which have a cistern in the roof.

4875. Can you tell us the proportion of houses of that class which are supplied with this tap over the sink?—I cannot. There have been a great many put up during the last four or five years.

4876. Has that privilege been abused by the occupiers of the houses?—Not to any great extent.

4877. There has not been much found to result from it?—There is more waste from the common stands no doubt than from the taps in the private houses.

4878. Then in your judgment the principle of a direct supply at constant pressure would be a principle of economy in the interest of the Water Company?—No, I do not think so. There are a great many leakages in the streets, both in the services and in the pipes themselves, and I do not think it would be a source of economy to the company, I think it would be a loss to the Company.

4879. Have you cast mains?—They are cast mains.

4880. How are they jointed?—They are jointed in the ordinary way with lead.

4881. I suppose you, as an engineer, are prepared to state that pipes can be obtained of sufficient strength and perfection to resist the pressure necessary for the constant supply?—There is no question of that at all.

4882. Then the waste is due to the condition of the pipes in Sheffield now?—No doubt it is so.

4883. And if those pipes were put into a proper condition, you think that there would be no waste?—Quite so, from that cause.

4884. If put into a proper condition is it your opinion that the principle of a constant supply would be better, all other things being equal?—I do think so.

4885. In 1869 the company will be obliged to give a constant supply, will they not?—They will.

4886. Will that constant supply be limited to 12 hours a day as now, or will it be 24 hours?—It will be day and night.

4887. In your judgment will it be necessary for the company to repair the pipes or to lay down pipes of a sufficient strength to resist the pressure?—I think so.

4888. And also to attend to the joints between this and 1869?—I think that a great many of the pipes in the Sheffield streets will require renewal before that time, at all events to avoid the immense leakage which must occur unless they do.

4889. In the new parts of Sheffield, where pipes have been laid down recently of sufficient strength and properly jointed, have you heard of any complaints of the waste of water?—I have not. Having the control of the public streets of course the immense number of breakages we have in our pipes in the Sheffield streets come under my notice.

4890. What does that breakage arise from?—It arises I think in the first place from the corrosion of the pipes from their having been down such a length of time, and in the next place of course there is a large head of water and a great pressure upon them. This causes a great many breakages in the streets.

4891. Your pipes are in the subsoil of course?—Yes, they are in the subsoil.

4892. You have no subways, I believe, as they have in Nottingham?—We have no subways.

4893. Do you think that the system of subways would be an advantage?—I do think so. I think that the water ought to be got at without picking up the public carriageways so frequently as we have to pick them up in our town.

4894. With the exception of the decay of the pipes and the want of capacity to resist the pressure, you are in favour of a general system of supply with constant pressure?—I am. I think that when towns can be supplied under constant pressure as easily as is the case at Sheffield, they ought to be supplied. From the large gathering ground that we have available, I think it is imperative that the water company should supply us under constant pressure.

4895. What is your head of water?—Our highest service reservoir is about 400 feet above the lowest parts of the town.

4896. How far is it from the town?—About $2\frac{1}{2}$ miles from the lowest part of the town, the storage reservoirs are at least 600 feet or 700 feet above the service reservoirs.

4897. But your head of water would be from the lowest reservoir?—It would; but the town is increasing above the level of the present highest storage reservoir, and they have contemplated that they will be obliged shortly to construct a storage reservoir at a higher level upon the line of the conduit, and they have obtained power to buy land for that purpose.

4898. Would not 400 feet carry it to the top of any house in Sheffield?—No; the town is increasing up the hill to a higher level, above the present service reservoir in fact, but for the great bulk of the population the head will at least be on an average of 200 feet of height.

4899. Has there been any discussion in the board of health or in the council as to the propriety of taking charge of the water?—In 1864 at the time of the disaster, there was a discussion as to the propriety of doing it, but there was no action taken upon it.

4900. Do you know the capital of the company, I mean the increased capital which will be necessary to enable them to complete their works in 1869?—They sought for a further capital last year of 800,000*l.*, but one portion of the scheme, the watershed of the Little Don, was struck out, and I think it would now be some 400,000*l.* additional. They have had a capital of 1,160,000*l.* prior to the present year.

4901. Then that would make 1,560,000?—Yes.

4902. Do you know what dividend they are paying?—Three per cent. was the last dividend, but it was five per cent. before the accident.

4903. Has the reduction from five to three per cent. been in consequence of the accident?—Yes, it has been in consequence of the accident, and in consequence of the additional capital for paying off the costs of the accident.

4904. Do you see any difficulty in preventing the occupiers of small houses wasting the water by instituting some principle of inspection?—I think they have the power of inspection, and penalties are inflicted on detection; there is no difficulty at all in controlling them.

4905. Do you think that the people of Sheffield would not rise in rebellion against any such inspection?—Certainly not.

4906. (*Mr. Harrison.*) You were asked a question which you did not follow up, which was with regard to your corporation having it in contemplation to take the waterworks; will you tell us what was done with regard to that?—An offer was made to the company during the progress through Parliament in 1864 of the bill asking for powers to raise further capital to pay off the costs of the disaster, but the company did not accept that offer. The offer was made after a resolution was passed by the council in the committee room, but no further action has been taken upon that matter.

4907. (*Chairman.*) What is the scale of charge by the company in Sheffield; are they guided by the rent of the house?—It is about five per cent. on the rental, and 25 per cent. upon that for 7*l.* a year house and under; the rate was fixed by the Act of 1864, including the 25 per cent., and they obtained under that Act an addition to their previous rate, making it 8*s.* $11\frac{1}{2}d.$

4908. Have they power to charge 30 per cent. on the rental?—They have power to charge pretty nearly equal to that upon 7*l.* a year; it really would in cottage houses amount to that.

4909. What I understand you to say is this, that their original power was to charge five per cent. upon the rental of any house?—Yes.

4910. And they subsequently obtained powers to charge 25 per cent. more ?—They did.

4911. Is that 25 per cent. of the five per cent., or what ?—25 per cent. upon the rate which would arise, upon the five per cent.

4912. Therefore it would be between six and seven per cent. ?—Yes.

4913. Is that for small houses, or is it a scale operating on all the rentals ?—It is a scale operating on all the rentals. The rate on 7*l.* and under is 8*s.* 11½*d.*; 7*l.* and under 8*l.*, 10*s.*; 8*l.* and under 10*l.*, 12*s.* 6*d.*; 10*l.* and under 12*l.*, 15*s.*; 12*l.* and under 15*l.*, 17*s.* 6*d.*; 15*l.* and under 18*l.*, 20*s.*; 18*l.* and under 20*l.*, 22*s.* 6*d.*

4914. Then the rule is carried out throughout ?—Yes, for houses of 100*l.* and upwards it was 3 per cent. upon the rental under the Act of 1853, and under the Act of 1864 it was 3¾ per cent. upon the rental.

4915. What do they charge for manufacturing purposes, what they call their wholesale customers ?—10*d.* per 1,000 gallons, and 25 per cent. upon that 10*d.*, making 1*s.* 0½*d.*

4916. (*Mr. Harrison.*) Having reference to the special inquiry of this Commission what are the chief points to which you wish to direct our attention at the present moment as regards Sheffield ?—The chief point to which I should like to draw the attention of the Commission is the want of supply for sanitary purposes. They have the power of charging us like other consumers 1*s.* 0½*d.* per 1000 gallons for the water used in watering the streets, or flushing the sewers, or anything of that kind. We should have power under the Local Government Act to take them to a reference upon the question of rate, but still I think it would be very desirable indeed that Parliament should itself have fixed a lower rate for the water used for sanitary purposes.

4917. That is substantially the point to which you wish to direct the attention of this Commission ?—Yes, it is.

4918. Bearing on that point you are aware, I presume, that in several towns such as Glasgow, Manchester, and Liverpool, the corporation have taken the waterworks into their own hands ?—I am aware of that.

4919. And with beneficial results in all those cases ?—Yes, I believe that to be so.

4920. At present it is quite an open question, is it not, in the case of your corporation ?—I am afraid it is a question of such magnitude that it will frighten the Sheffield people for a great number of years; you see the immense capital that they have, and the increased capital, owing to the disaster, of something like 400,000*l.*, that is dead capital, and it would require an immense sum to purchase their waterworks.

4921. Looking at the position of Sheffield there is hardly any town in the kingdom, is there, that is better situated for getting a supply of water ?—There is no town in the kingdom better situated for getting it by natural gravitation. We have very valuable works on the streams, and it enhances the cost of the water to the inhabitants to compensate the owners of those works by compensation reservoirs. I believe that the cost of those compensating reservoirs increases the cost of the water to the inhabitants more largely than in most places.

4922. Are not all of those valleys open to you going up towards Chesterfield ?—Yes, those valleys going up towards Chesterfield direct are open to us, but the water is not so pure. There are some beds of coal and it is being got in several places, and there is a great deal of ochre water thrown into the streams which renders the water unfit for domestic purposes.

4923. If it had not been for the failure of the Dale dyke reservoir you would before this have had an abundant supply ?—We should have had an abundant supply of water of first-class quality. There can be no dispute as to the quality.

4924. Then the point upon which you really feel aggrieved is the price which the company under their Acts of Parliaments have the power of charging for sanitary purposes ?—That is so

4925. I suppose that is a point which you have contested before the committees of the Houses of Parliament this session ?—No, not this session. We contested the 25 per cent. most strongly in 1864, but it was given for 25 years in spite of our opposition. I will read to the Commission the resolution passed by the Council in 1864. "Resolved that in the opinion of "the Council it is desirable that they should purchase "on behalf of the inhabitants of Sheffield, the works "of the Sheffield Waterworks Company upon sums "hereafter to be agreed upon rather than an advance "of 25 per cent. should be sanctioned upon the "present water rate."

4926. (*Chairman.*) Were not the water company before Parliament when that resolution was passed? Yes, "Resolved further that it be an instruction to "the committee appointed to oppose the Sheffield "Water Company's Bill, and they are hereby requested "to communicate the above resolution to the Sheffield "Waterworks Company for the purpose of ascertaining their views thereon, and at the same time offer "to purchase the waterworks on the following terms, "namely. Upon terms that shall secure to the company as a consideration for such purchase either "perpetual annuities equal in the aggregate to 2*l.* per "centum per annum upon the present share capital "of the company and an indemnity from their mortgage debts and from their liabilities incurred by the "bursting of the Dale Dyke reservoir, or such a sum "equal to the value of the undertaking immediately "before the inundation, after deducting therefrom the "sum of 40,000*l.* being the estimated cost of reconstructing the said reservoir, and also deducting the "amount which shall be paid by the company for "damage or compensation in consequence of the said "inundation, on which shall be assessed for damage "or compensation consequent on the said inundation, "and also providing for the transfer to the council "the mortgage debts of the company, the amount of "such mortgage debts not to exceed the aggregate "amount of the principal monies due by the company "on mortgage or bond, or to take to the works on "terms to be settled by arbitration if Parliament "will so permit, and if the company will not accede "to any of the above terms whether they would be "disposed to transfer such works to the corporation "on any other terms."

4927. (*Mr. Harrison.*) Not having been successful in accomplishing that object, what can you suggest that this Commission would be able to do to relieve you in any way ?—I am afraid that after Parliament has given them the 25 per cent. and they upon that clause having borrowed a large amount of capital to pay the compensation due to the sufferers from the disaster, it is a matter which it would be difficult to manage.

4928. Taking the towns that lie on the river below you, for instance Rotherham or Doncaster, or going further on, Thorne, and then going to the east of all Goole, would not this water company when they have completed the whole of the works which are now authorized have an abundaut means of supplying the whole of those towns with water ?—They would, I believe, on the present population, and if they had not sufficient, there is still further available gathering ground for increasing those works.

4929. Has it ever occurred to you that in the case of a number of towns so situated as those I have just mentioned, and, of course, all the intermediate villages the grouping together of a large district might be a desirable thing ?—If the district were sufficiently closely populated to warrant the expenditure in pipes running from one district to another it would no doubt be a great advantage. I believe, that ultimately the whole of the valley of the Don from Sheffield to Goole will be so thickly populated, in fact, within a very moderate number of years as to warrant such an expenditure as that, and it would pay well to take the water from our hills down there.

4930. In the consideration of the question of purchase by your corporation did you ever take into

S. F. Holmes, Esq.

6 June 1867.

account the possibility of such an extension?—We have not done so.

4931. The Agden reservoir was about half completed at the time of the fall of the Dale Dike, was it not?—Yes, it was.

4932. Is it now nearly completed?—It is getting very rapidly on. They are proceeding very rapidly with that reservoir in order to give us a supply in 1869.

4933. They have altered their mode of induction pipe, have they not?—Yes, they have, and they have strengthened the embankment also, and widened it out.

4934. Then the whole of that water which you now get from your Rivilin reservoir there is as pure as anything can be?—It is.

4935. And even when you go up to Dale Dyke you can get almost into the immediate neighbourhood of the millstone grit?—Close to it, it crops out close to it.

4936. As far as your prospects go you have water of quantity and quality infinitely more than you can possibly use?—Yes, and we have new Parliamentary powers also for all we can possibly want.

4937. The only complaint you have is that for sanitary purposes you to have pay too high?—Yes, and also as regards the rates, there is a very strong feeling in the town that we pay too much by 50 per cent. for our water.

4938. The only remedy for this appears to have been that the town should have purchased them?—Yes.

4939. Is Mr. Hawkesley acting now as engineer to the Sheffield Waterworks?—Yes, and I must admit that the work now at Agden looks to be of a very different character from the manner in which the Dale Dyke reservoir was constructed. They are certainly doing it now on excellent principles, and they are proceeding very carefully with the work and rapidly also.

3940. (*Chairman.*) Are they using other materials than those used in the Dyke Dale which gave way, or are they simply increasing its base?—They are increasing its bulk, and they are managing it so as to put next to the puddle a comparatively impervious material to support the puddle before it was thrown in indiscriminately, but now they are putting it in layers upon the bank, and raising it gradually.

4941. What is the measurement of the top square of the bank for the incline?—At the top it would be something like 30 feet when it is finished.

4942. How much at the bottom?—At least 500 feet or 600 feet; it is one of the strongest embankments I have ever seen.

4943. (*Col. Harness.*) What is the greatest height?—90 odd feet.

4944. (*Chairman.*) Are there any other points that you are authorized to lay before this Commission besides the question of the 25 per cent?—There has been a strong feeling in the town against it, but I do not think it is much use now exhibiting it.

4945. If Parliament have sanctioned it, and the company have borrowed money on the strength of that Parliamentary right, it would be scarcely possible for this Commission or any other body to interfere with it?—No; but there is another question which has lately arisen.

4946. Has the town of Sheffield any idea of going to Parliament for compulsory powers to purchase the water company?—Not the slightest idea at present, it has never been mooted.

4947. What is the rateable nature of the property in Sheffield?—It was 544,000*l.* in the year 1866.

4948. What rate of increase is going on in Sheffield?—In 1848 the rateable value was 272,161*l.*; in 1857 371,679*l.*, and at the end of 1866, 544,000*l.*

4949. I think you were about to state some other point to which you desire to call the attention of the Commissioners on?—The company are now requiring the council to put down at each stand for watering the streets a meter and the meters will cost 20*l.* each.

4950. Have they the authority of Parliament to call upon you to do so?—They have; but the meters will cost 20*l.* each, and they offer either to allow us to put them down at our own cost or to put them down themselves and charge us 10 per cent. upon the amount as rent, It is a very serious matter when you come to have 50 or 60 stands with meters costing 20*l.* each.

4951. When you speak of stands do you mean cab stands, or what?—In fact you may call them sluices in which they insert pipes to take water from the mains for watering the streets and to which they attach stands.

4952. You mean for sanitary purposes?—Yes, we require 50 at the present time; that would be 1,000*l.*, of course 10*l.* per cent. upon that is 100*l.* for rent of meters only, which is a very serious question.

4953. Are you under a contract with the company to pay them so much for all the water that you require for those purposes?—We are negotiating for a contract.

4954. How have you paid the company for the water used for sanitary purposes up to the present time?—It has been more by guess more than by anything else; of course they know what each of the barrels hold and they know the number of times per day that it is filled and that measures the water.

4955. Have you had no agreement between the company and the corporation?—No never.

4956. Has the amount varied from year to year?—Yes very much.

4957. And do they allege that you have been using more than you ought and hence the necessity for those meters to check the increased consumption?—They do not; they simply allege that it is now time that we had some arrangement, and they think that as a trading community they are bound to measure out what we do take.

4958. What do they charge you per 1,000 gallons?—We have no fixed price, we are negotiating that at the present time.

4959. Failing a satisfactory settlement between you and the company have you any right of reference?—We have the right of reference under the Local Government Act, and there is a clause also in their Act of 1864 enabling them to sell water to the town at a less price than to other consumers.

4960. Has the arbitrator power under that general reference to fix the price at which the town should be supplied?—He has. This is the clause in the new Public Health Act, the 11th and 12th of Victoria, chapter 63, section 75, "In case any difference shall "arise as to whether the water which any such com-"pany is able and willing to supply or lay on is "proper and sufficient for the purposes for which it "is required by the said Local Board, or whether the "purposes for which it is required are reasonable, the "same shall be settled by arbitration in the manner "provided by this Act."

4961. Are you quoting from the Board of Health Act, the General Act?—Yes.

4962. Which Act you have adopted?—Yes.

4963. Is there any other point which you wish to bring before the Commission?—Not any that I am aware of.

The witness withdrew.

Mr. JOHN JACKSON examined. *Mr. J. Jackson.* 6 June 1867.

4964. (*Chairman.*) Are you the chief constable of Sheffield?—I am.

4965. Are you desirous of making any statement to the commission?—No, I do not know that I could really add anything to the evidence already given by Mr. Holmes, the borough surveyor. I have with me a report which shows the condition we were in in 1864. I was desired by the town council to obtain information and to make that report. The information I furnished in detail, but that report is a summary of it.

4966. Do you desire to put this in?—Yes, I desire to put it in.

4967. This is a letter signed by "J. Jackson, chief constable," addressed to the town clerk, dated the 10th of October, 1864?—Yes.

4968. And it embodies the substance of your detailed return?—It does.

The witness delivered in the following paper.

John Yeomans, Esq., town clerk.

SIR, Town Hall, Sheffield, October 10th, 1864.

WITH reference to the resolutions of the committee appointed by the Town Council, "To consider the failure "or neglect of the Waterworks Company to supply water "according to the requirements of the law," I directed four officers to call at a number of the principal manufactories in the borough, and they have obtained the information contained in the returns transmitted herewith.

The officers report having visited 192 manufacturers, 81 of whom however are wholly, and 22 partially supplied with water from sources independent of the waterworks company: and of the 89 wholly dependent upon the company, 34 state that their workmen have lost nothing in consequence of the deficient supply, whereas, the remaining 55 say, the 4,399 persons employed by them, and renting power of them, sustain a loss in the aggregate of 1,522*l.* per week. Twelve manufacturers have sunk wells, and eight are leading water in barrels from different places to enable them to keep their engines and machinery working.

In the under-mentioned streets and places, water can only be got from the company's mains for four hours each Monday, Wednesday, and Friday, viz.: the Market Place, West Street, Glossop Road, Brook Hill, St. Philip's Road, Allen Street, Broad Lane, Westbar Green, Westbar, Gibraltar Street, Penistone Road, Langset Road, Walkley, Philadelphia, Green Lane, Allen Street, Corporation Street, Woodside Lane, Pitsmoor, Burngreave Road, Nottingham Street, Brunswick Road, Carlisle Street, Tinsley Road, Wicker, Blonk Street, Broad Street, Park, Cricket Road, Shrewsbury Road, Suffolk Road, Leadmill Road, Pond Street, Brown Street, Eyre Street, Matilda Street, top of Ecclesall Road, Devonshire Street, Eldon Street, Campo Lane, Paradise Square, Bank Street, Snig Hill, and the streets and places adjacent thereto, whilst in other parts of the borough it is only procurable for a like period each Tuesday, Thursday, and Saturday, This limited supply has been continued since 29th August last.

Householders generally complain of the inconvenience to which they are subjected by reason of their being unable to procure water each alternate day. Many have no suitable vessels in which to store it, and others allege that it becomes impure and unfit for domestic use when kept in their houses from Friday till Monday. Nearly all agree in saying that it would suit them much better if they could get it for an hour every day, instead of four hours on alternate days. Publicans especially complain of its impurity after being kept, and such as have country horses put up at their houses are unable to procure it in sufficient quantities.

Mr. Hicks' property at the top of Woodside Lane has been entirely without water for six or seven weeks, and the occupiers have been obliged to fetch it from Harvest Lane and other places.

I have the honor to be, &c.,
J. JACKSON, Chief Constable.

4969. (*Mr. Harrison.*) Is it your opinion that if the corporation had the entire control of those works in their own hands you would be able to apply the water for sanitary purposes more beneficially than you do now, do you feel hampered by the amount which you are obliged to pay for it?—Partially we do. Of late years we have not been able to get it in sufficient quantities.

4970. (*Chairman.*) In the year 1869, when you will have an abundant supply, would you have far more freedom in the discharge of your duty if the water were under the control of the municipality instead of a joint stock company?—No, I do not know that I should. It would be a mere question of price between the corporation and the company. If they had a sufficient supply of water and would allow me a sufficient quantity for sanitary purposes I should not feel in any way hampered.

4971. I find by the letter addressed to the secretary of the Commission by the town clerk that the resolution of the Improvement Committee is to this effect. "That the borough surveyor and chief constable be "requested to proceed to London to give evidence "on the present state of the water supply of Sheffield, "and that they be accompanied by Mr. Councillor "Ironside and the town clerk." The town clerk is here, and I merely ask whether he desires to make any statement to the Commission?

(*Mr. Town Clerk.*) I am obliged to the Commission for the offer, but I have no authority to make any statement.

The witness withdrew.

ROBERT WILLIAM MYLNE, Esq., examined. *R. W. Mylne, Esq.*

4972. (*Chairman.*) You are a civil engineer and architect?—I am.

4973. And also a Fellow of the Royal Society and Member of Council of the Geological Society?—Yes.

4974. Have you published some contour maps of the metropolis?—Yes; I published them 10 years since.

4975. Are you connected with any Water Company?—I am engineer to one at the present time. The Limerick Waterworks is under my charge.

4976. (*Mr. Harrison.*) The New River was under your father's charge for a good many years, was it not?—My father was engineer to the New River Company for upwards of 50 years, and my grandfather 42 years before him.

4977. (*Chairman.*) During your father's term of office did you take any part in the engineering works connected with the New river?—I at no time held any office under the New River Company, but for 20 years I had been associated with my father in all the works connected with the New River. Since his retirement in 1861 I have had no connexion with the New River Company's works.

4978. Can you state the power of supply from that source prior to 1861 when you were connected with it?—I do not think I can state the exact quantity supplied in 1861 but I know that at certain periods the quantities were made out for Parliamentary purposes, and they are in print. I assisted my father in 1854 in making out a return for the previous year.

4979. What quantity were they able to supply at that date?—Their supply amounted to an average daily quantity of 17,537,396 gallons.

4980. Have they taken any steps for the purpose of increasing the supply of the New River from the river Lea since the year 1853?—Yes; the New River has been considerably enlarged, and its length shortened from 35 to 22 miles. I may mention, that when the Parliamentary Inquiry as to the condition of the supplies of the several companies took place in 1851 and 1852, works were proposed and powers were obtained for carrying out extensive works which the New River Company executed at great cost between the years 1854 and 1857. At that time I entered into the question with my father of reorganising the entire works of the New River Company, in which Mr.

R.W. Mylne, Esq.

6 June 1867.

Lindley of Hamburgh also assisted professionally. Previously the New River Company supplied by gravitation from the level of the New River Head a very large portion of the city and all the low parts of their district. But the new works were designed by dividing the district into three distinct steps or levels of from 70 feet to 100 feet in height, each level having a service reservoir at its head containing a quantity based upon about 24 hours' consumption, the object of those reservoirs being to give a uniform pressure over the district, and to meet the increased draught during the earlier part of the day. Those reservoirs were carried out in three distinct terraces, and were supplied by steam power, raising the water from a series of newly constructed filter beds. I have a map here on which I can show to the Commission the district of the New River Company and the general features and situation of the reservoirs (*producing a map and explaining the same.*) This map is a contour map of 10-feet levels of the metropolis extending from Kew to Woolwich.

4981. Is the area coloured red, that which the New River Company supplies?—The areas coloured on this map do not represent the seven companies separately. they represent the New River in red and the East London in purple. The West Middlesex, the Grand Junction, and the Chelsea are united in one colour, green. On the south side of the river the Southwark and Vauxhall and the Lambeth Company are also united and are coloured orange. The map which I published in 1856 represents the seven companies in separate colours (*producing another map*). On this published map the New River district is coloured red and as I said before from the level of the New River running as a contour line along to the New River Head they supplied by gravitation all the lower portions of the city, Hoxton, Kingsland, and along the Strand. In a few instances where the houses were very high they used to receive extra pressure. The reservoir which is called the High Pond, at Claremont Square supplied a certain portion near and around the New River Head and away towards the west. There was one other small reservoir at Camden Hill and another at Tottenham Court Road, but independently of those there were no other service reservoirs. At Stoke Newington there were two subsiding reservoirs 43 acres in extent, which received the New River water, and passing through them flowed on to the New River Head. In 1852 the new works were designed, the gravitation from the New River Head was abandoned, and the Claremont Square reservoir was heightened 10 feet and enlarged and covered and served by engines at the New River Head as before. That is the lowest reservoir now actually supplying, as far as I am aware, any portion of the New River district. Its level is 126 feet above Trinity high-water mark, the highest services reservoirs are 414 and 433 feet.

4982. I presume the object of distributing those reservoirs over the district was to equalize the supply?—The object was to obtain an average pressure of from 60 to 70 feet in the several parts of the districts, and the design anticipated the adoption of a supply under the constant system.

4983. Can you state whether any reservoirs have been formed in the upper part of the Lea for the purpose of storing the storm waters so as to increase their volume?—I desire presently to speak specially upon that point. My answer to that, so far as the New River is concerned, is that no large reservoirs have been formed for storing the flood waters of the Lea. The East London Company have made reservoirs in the valley of the Lea, low down, for storing to a small extent the freshes.

4984. Do you see any difficulty in forming reservoirs so as to increase the volume of the New River?—Upon that subject, after describing any points with regard to the metropolitan district, I should propose to read some notes in explanation of a proposed scheme for storage.

4985. Will you explain to us first the quantity that you are at present able to supply; secondly, how you propose to increase that supply; and thirdly, what is the character of the water which you are supplying?—In the first place, not being officially connected with the New River Company, I can only state what their present quantity is from the evidence which has lately been given before the Pollution of Rivers Commission, and also returns given into the committee which is now sitting at the House of Commons. In 1853 the quantity supplied by the New River and East London Companies was a daily average of 29,528,385 gallons.

4986. As an engineer, do you see any difficulty in forming reservoirs in the upper part of the River Lea to store the storm water so as to utilize it and increase general volume?—Upon that point I had perhaps better read a statement which will briefly explain my views.

4987. Can you shortly state whether as an engineer you see any difficulty of forming reservoirs at a given point or points, and storing a sufficient quantity of water to increase considerably your capacity of supply?—In reference to the upper tributaries of the Lea, on the Lea proper above Hertford, there are difficulties in obtaining sites for making reservoirs that would be likely to be sound and efficient. I have here a map showing a scheme which I should propose to carry out, which will bring 70,000,000 gallons into London (*producing another map*). I do not mean 70,000,000 gallons additional to the present supply, but by doing away with the present New River intake and the East London intake and consolidating the two companies, so far as sources go, there can be brought into London from storage reservoirs made on the London clay, the detail of which I can explain if necessary. The scheme would give for the East London districts 30,000,000 gallons per day by gravitation from high-level reservoirs delivered on Stamford Hill at the level of 112 feet above Trinity high water mark.

4988. Will you first describe your area, and then the rainfall due to that area?—I have not prepared any calculations based on the data of rainfall, but upon gaugings and observations on the actual volume flowing down the Lea. I would first say that it is to be gathered from various official documents that the New River Company during the past year abstracted from the river Lea an average daily quantity of about 18,000,000 gallons of water at their point of intake, one mile and a half below the commencement of the navigation of the river Lea at Hertford, and the East London Waterworks Company from the same river abstracted at a point near Tottenham, 20 miles below Hertford, an average daily quantity of nearly 19,500,000 gallons of water, making in all 37,500,000 gallons taken during the year 1866 from the river Lea for metropolis supply. The first-named quantity is conveyed by gravitation along the New River open aqueduct, 22 miles in length (and in part by pipes), into reservoirs at Hornsey and Stoke Newington, at the level of about 87½ feet above Trinity high-water mark; and the East London quantity is conveyed along an open conduit, 1¼ mile in length, to reservoirs at Lea Bridge, at the level of 7½ feet above high water, making a difference of level between the two companies stations of 80 feet. Besides the quantity derived by the New River Company from the river Lea, there was obtained from the Chadwell spring and other sources about 5,000,000 gallons, making altogether a total daily supply to the metropolis during the past year by the two companies of 42,500,000 gallons, and this quantity was distributed amongst a population of 1,500,000 inhabitants, representing a moiety of the entire population of the metropolis. As respects the watershed area and population comprised within the Lea basin, above the respective points from which the two companies draw their supplies, it has been ascertained from recent examination that above the New River intake the area is 264 square miles, with a present population of about 73,500 persons, or 278 per square mile; and the East London Company an *additional* drainage area of 219 square miles,

including 79,500 inhabitants, or 363 per square mile; the total being 483 square miles, with a population of 153,000 persons down to Ponder's End, below which point the East London Company have diverted all further drainage from entering that part of the Lea, from which their supply is derived. The principal streams forming the tributaries of the Lea consist, in the upper division of the Lea proper, the Mimram, the Beane, and the Rib, all of which unite and flow down to the point of the New River intake; and the Lea is further augmented in the lower division by the Ash and the Stort, at the junction of which latter river the entire volume passes through Feilde's weir, situated two miles above Broxbourne. I would wish to mention that the quantity which I propose to take from the gathering ground, which I have marked green on the map, is based not upon rainfall but upon measurements taken at Feilde's weir.

4989. Then that is the net result of what finds its way into the river?—Yes. I do not in any way touch upon the question of rainfall; I take the quantity as ascertained at Feilde's weir.

4990. How often have those gaugings been made? In the years 1851 and 1852 some careful gaugings of the daily discharge at Feilde's weir were carried out by Mr. James Simpson, as umpire between Messrs. Beardmore and Smith, the arbitrators appointed to determine the millowners interest arising from a scheme, under the advice of the late Mr. Rendel, of disposing of the surplus water of the river Lea. Although there was no further necessity for continuing the gaugings, they have been regularly kept and recorded, under the superintendence of Mr. Beardmore, the engineer to the river Lea Trust, who it is to be hoped will shortly collate the details and publish them, as a valuable addition to his already extensive information on the flow of rivers. I am informed that Mr. Beardmore has already given in evidence to this Commission the yearly returns of those gaugings, but he has permitted me to look carefully into the monthly and daily returns, by which means I have had the opportunity of ascertaining the surplus and deficiencies on every day over each year. From an examination of these returns it appears that in the Lea valley two periods of great drought during the past 17 years have occurred, viz., in the years 1858–59, and 1863–64–65. The discharge at Feilde's weir due to the watershed area of 416 square miles, [exclusive of Chadwell spring,] was on the average during the respective periods very nearly alike. That is to say, 1858–59, and 1863–64–65, were nearly the same, and although it was so extremely dry in 1865, the average of the three years exceeded that of 1863 and 1864.

4991. That was accounted for by the fact of the springs not being exhausted?—Yes, it was chiefly accounted for by the fact that there were several more months of continuous drought in 1863 and 1864, than in 1864 and 1865. The average discharge for the two periods of great drought was 7,860 and 8,040 cubic feet per minute respectively, but the average of the two years 1863 and 1864 was below that point, and did not exceed 7,355 cubic feet, a quantity equal to 66,000,000 gallons per diem. The yield, however, of the three consecutive driest months in 1864, viz., August, September, and October fell to as low an average as 3,980 cubic feet per minute, and if from this be deducted the amount to which the Trustees of the river Lea have a prior right for the maintenance of the upper division of the navigation, viz., 400 cubic feet per minute, it would leave an available quantity during those three months for valley uses, and water supply of only 32,000,000 gallons per diem, a quantity less than the average daily abstraction during the past year from the river Lea by the New River and East London Water Companies. Below Feilde's weir down to Ponder's End there is an additional area of 67 square miles of drainage into the Lea, but it is chiefly of a low-lying clay country considerably populated, which would yield but a small additional quantity in very dry seasons. There are, however, some copious springs which rise between Feilde's weir and Broxbourn which augment the river to the extent in dry weather seasons of about 6,000,000 gallons per diem. It has been stated that the mean discharge due to Feilde's weir of the two successive driest years over a series of years, amounts to 66,000,000 gallons per day. This quantity may be divided under the following heads, 1st, the upper division above the New River intake, 45,000,000; 2ndly, the Lea below Ware together with the Ash and the Stort, 13,000,000; and thirdly, from springs rising between Amwell and Rye House, 8,000,000, making together 66,000,000. I may observe that these quantities are based upon various experiments and observations which have been made at different times, and also upon evidence which has been given upon the subject. The tributaries yielding the volume due from the upper division (264 square miles in extent), give a much more uniform and regular flow throughout the year than those below, and heavy floods seldom occur, arising chiefly from numerous springs issuing from an extensive chalk district, the greater part of which is covered with large tracts of sand and gravel which act as a permeating medium of storage, equalizing the flow and giving their maximum discharge in the summer season. In the second division (152 square miles) the river Ash runs through a chalk and clay district, and the floods are moderate, but the Stort drains an area consisting almost entirely of tertiary and drift clays, and is subject to great freshes in wet seasons, and is practically dry at times of extreme drought. As respects the springs between Amwell and Rye House, they vary in volume and are affected in colour in wet weather, but their discharge is highest in summer, and those between Hoddesdon and Broxbourn below Feilde's weir are of a much more permanent character, probably arising from a considerable extent of drift area to the westward. The origin of the whole of them, however, it is not improbable may be attributed to a local change in the dip of the chalk, consisting of a gradual depression along the escarpment of the tertiaries extending over 10 miles or more, from Hatfield eastward by Bayford and Rush Green to Rye House and Hoddesdon, at an inclination of about 20 feet per mile, the line of which is nearly at right angles to the general dip of the chalk basin. There is, however, another feature lying beyond the watershed drainage area of the Lea which there can be little doubt has an important bearing on the source of these springs, viz., the existence of an isolated clay catchment basin of 23 square miles, which has no direct surface outfall, the central and lowest part of which is between North and South Mims where the surface is chalk, and several swallow-holes exist in the locality which receive and absorb the drainage water of the district. The natural tendency in this case would be for the waters to flow in the direction of the general dip of the chalk basin, but from the inclination of the strata towards the east, there can be no doubt a considerable portion of the water is carried off in that direction. There is a small ridge at North Mims separating this catchment basin from the Colne valley (*pointing to the map*), the entire volume of the drainage shoots down from off the clay lands on to the chalk, and pours into numerous swallow-holes and entirely disappears; within the last fortnight floods came down here (*pointing to the map*) with greater force than has perhaps been known for several years, it attained a depth of 10 feet over a small area of ground, and rose to within a few inches of the top of the ridge, but it all passed away into the swallow-holes, and does so continually.

4992. (*Mr. Prestwich.*) Your impression is that the water which disappears at the Mims issues again in the form of springs in the neighbourhood of Hertford?—Largely between Hertford and Hoddesdon, but a considerable portion of it also finds its way towards the south-east in the direction of the dip of the basin.

4993. Would it not be more likely to flow towards London, that being the point at which the chalk is at

R. W. Mylne, Esq.

6 June 1867.

its lowest level?—I think not, for the chalk is very flat for some miles before reaching London.

4994. (*Mr. Harrison.*) Is the dip of the chalk a regular one, or is there any fault in it?—I think there is no fault but a disturbance to the eastward.

4995. (*Mr. Prestwich.*) Would not a great deal of this water which disappears in the neighbourhood of the Mims go to supply the wells in London?—A portion of it no doubt. At the wells at Cheshunt the chalk is reached, but the supply is not large. At a well at North Mims only a few yards within the Colne watershed, the water stands at 60 feet from the surface, although to the east of the ridge 10 feet of water accumulates at times above the surface, sweeping away into the swallow-holes. How far that is a ground for supposing that this area supplies the springs I do not know, but I advance that as a probable origin. The source of the Chadwell spring, though deep seated, may possibly be influenced from the same circumstances, and its volume, though variable, may be taken at about 4,500,000 gallons per diem. It flows, together with the water abstracted from the Lea, along the channel of the New River, which has bays or stop-gates on its course to restrict and regulate the flow, giving a velocity to the stream of from three quarters to one mile per hour throughout. As regards the fall of the river, the difference of the level of its bed between Ware and Enfield, 13 miles in length, gives an average of about 4½ inches per mile, and from thence to the Hornsey reservoirs, a distance of 6½ miles, a fall of 11 inches per mile. That difference in the fall has a bearing upon the scheme, because I adopt the lower length of the channel of the New River to carry a greater volume of water than at present. The inclination of the surface of the valley of the Lea from Hertford to Hoddesdon falls at the rate of four feet per mile. The width of the valley in the upper portion is on an average about half a mile, and its subsoil consists of from 12 to 15 feet of coarse calcareous gravel overlying chalk, with a superstratum of loamy clays. These gravels contain a large mass of water, which boils up on being disturbed, evidently deriving its source from subterranean springs, which, issuing from the eroded sides of the chalk and flowing down the valley in the gravel, give rise to a few surface springs, but the greater part of the water never appears above but is absorbed and soaks away in the outcrop of the sands underlying the London clay, which commences southward in the valley between Hoddesdon and Broxbourn. This volume, it is suggested, might with advantage be collected for water supply, as it is now lost under the London clay, and trends away to a great depth in a south-easterly direction towards the mouth of the Thames. The question of storing the freshes of the upper tributaries of the Lea by the construction of impounding reservoirs has been frequently discussed, but only on one occasion has the matter been put forward in a definite and comprehensive shape. In the year 1852 the late Mr. Rendel in association with Mr. Beardmore designed two large reservoirs on the Lea above Hertford, also one on the river Rib, and a third on the Ash, the object being to obtain an average daily supply of 90,000,000 gallons. Parliamentary notices were given and a bill deposited for this scheme, but it dropped from the want of combination of various contending interests. Since that period no suggestions have been made to store in the upper tributaries of the Lea, and it has become a generally accepted opinion that there would be some difficulty in finding sufficiently extensive sites on impermeable soils for the requisite reservoir areas and this has led to the statement that if the freshes are to be stored it must be done at a point in the valley below Broxbourn, where the London clay commences. Mr. Beardmore has given some evidence upon that point, and it is stated in the Report of the Pollution of Rivers Commission that if the waters are to be stored and impounded they think from the evidence given that it can only be done by making a large reservoir at that locality. The whole of the water in the Lea except such quantity requisite for the maintenance of the navigation became under an Act in 1855 the property in equal moieties of the New River and East London Companies, and all the watermills on the course of the river below Ware have been purchased and now belong to them and the Lea Trustees, excepting the Government Ordnance factory and two other proprietors; the consequence, therefore, from the companies being masters of the water rights of the valley impounding reservoirs could now be carried out with more unity of purpose and less interference of vested rights than formerly. It being proved that in very dry seasons some difficulty is experienced in obtaining out of the river the full draught at present required by the two companies in the summer months, and seeing that the East London Company have sought powers this year to increase their supply from the River Thames above Kingston to the extent of 10,000,000 gallons per day, and that the present consumption of the New River Company amounts to the full extent of their powers and produce of the Lea in its minimum condition at Ware, and are thereby chiefly dependent for future increase on springs and chalk wells situated *within* the basin itself, and further from the recent Inquiry on the condition of the Lea by the Commissioners for preventing the pollution of rivers, it is not unlikely that extensive drainage works will be required; whether taking all these circumstances into account the time has not now arrived when the subject of impounding reservoirs should not be seriously entertained, and thus obtain an increased and improved quantity from the Lea valley for the supply of the present and future wants of the northern and eastern portons of the metropolis. To store the freshes below Broxbourn at the level of about 60 or 70 feet above Trinity high-water mark would only embrace a means of gravitation to the present works of the East London Company and would involve a lift of from 30 to 40 feet into the level of the New River, and would also necessarily involve expensive works for the removal of the drainage of the upper towns both on the Lea and the Stort. In contradistinction to the view recently put forward, that no means of storage could profitably be carried out without descending as low in the valley as Broxbourn or Waltham it is herein suggested that a considerable quantity from the upper tributaries mostly of pure spring water might be diverted and transferred by gravitation from a point above Hertford direct to convenient sites for reservoirs at Enfield Chase on the London clay beyond and altogether outside of the watershed of the upper portion of the Lea basin, and a further quantity might be impounded within the basin in the valley of the Rib. It is proposed to make diversion cuts on the before-named four tributaries, viz., the Lea proper, the Mimram, the Beane, and the Rib, and convey the collected quantities along an artificial channel to a point in the valley 2½ miles above Hertford; the total contributing area would be 246 square miles, giving an average daily yield of 43,000,000 gallons, but it is only proposed to take 40,000,000 gallons, and to convey that volume in a direct line to London through a tunnel and covered channel 5½ miles in length into reservoirs proposed to be made on Enfield Chase. The two proposed reservoirs to be made, into which the waters would gravitate, will cover an area of 270 acres, and will contain, including the tunnel, 1,391,000,000 gallons, with a top-water level of 130 feet above Trinity high-water mark and a maximum depth of 37 feet of water. I have brought with me a plan showing the reservoirs mapped in detail on the large scale Ordnance Sheets (*producing a plan and explaining the same to the Commissioners*). To command such level from the four tributaries it would be necessary to form diversion cuts, first at the level, on the Lea a few yards below Woolmers Park; secondly, on the Mimram, from the lower part of Panshanger Park above Hertingfordbury; thirdly, on the Beane, from a point some distance below Watton Woodhall Park; and fourthly on the Rib above Wades Mill. In order to increase the extent of reservoirs on Enfield Chase, and

to bring a higher water level into use for distribution it is proposed to construct four further reservoirs at the additional height of 36 feet and to lift into them by steam power a considerable portion of the collectable quantity entering into the two gravitation reservoirs previously described. These will cover an area of 340 acres and will contain 1,249,000,000 gallons, with a top-water level of 166 feet and a maximum depth of about 38 feet of water. The total storage capacity of the six reservoirs on Enfield Chase would therefore amount to 2,640,000,000 gallons or 423,552,000 cubic feet. The execution of the tunnelled part would be throughout its length entirely in chalk (*producing a section and explaining the same to the Commissioners*) and being near to the upper surface of the chalk and overlaid with tertiary sands and intersecting the local disturbance already alluded to, as well as across the general dip of the chalk, no doubt a considerable quantity of water may be expected. It is assumed that from the tunnel works, with the additional seven square miles of gathering ground at its southern end, together with the Lea tributaries, it will secure a total daily yield of at least 47,000,000 gallons. The storage capacity necessary for securing a uniform daily flow has been ascertained at Feilde's weir to be 118 days for 66,000,000 gallons a day, and inasmuch as the volume is proportionably much larger and more constant from the upper tributaries, it is estimated that a provision of 90 days storage would be quite sufficient for the intended gathering ground. On the Rib it is proposed to adopt the plans designed by the late Mr. Rendel for a reservoir below Standon, which exceeds 200 acres, and would hold above 500,000,000 gallons, with a maximum depth of 20 feet of water, and below that again between Thundridge and West Mill a good site for a reservoir exists, as also above Watton, where strong drift clays are to be found in the valley of the Beane, between which two sites the necessary storage capacity for the remaining quantity may easily be obtained. Along the eastern side of the Rib reservoir it is proposed to make a catchment channel to receive the town drainage from a conduit to commence at Buntingford, and including on its course Aspenden, Braughing, and Standon, all of which now drain into the Rib and enters above the New River intake, the catchment channel will also take extreme freshes, and at its lower end by a tunnel 1,800 yards in length will divert the waters into the river Ash; the drainage of all these towns now comprise the principal population of the Rib area. Below, at West Mill the storage waters are proposed to be conveyed through a tunnel 3,000 yards in length to a point in the Beane valley a short distance below Stapleford, and joining at its lower end the diversion cut from the Beane itself, the united waters will pass by open channels and tunnels to the Mimram and thence to the Lea and terminating at the intended main tunnel mouth 2½ miles above Hertford. On the site of the proposed Rib reservoir numerous borings were made for the late Mr. Rendel to test the character of the soil, which showed variable loam and clay beds, and on the slopes and caps of the hills there are extensive beds of strong drift clays, from these conditions there can be little doubt as to making a sound reservoir. The reservoirs on Enfield Chase are all situated on a bare London clay surface, with drift gravels occurring at places on the margin of the upper or high level reservoirs. Considering that the locality is within 10 miles of London, few sites of a more favourable character could be found. Over the entire area of 610 acres only one residence and three farm homesteads of no great importance are interfered with, and residential damage to adjoining properties can hardly be said to exist. The character and extent in area and embankment of the largest of the two gravitation reservoirs of 210 acres assimilates closely to the one on the Brent near Willesden nine miles distant, which also stands on the London clay, and is 222 acres in extent, and has been in use for more than half a century as a supply to the Regent's canal. Besides the works contemplated for the diversion of the upper tributaries of the Lea it is intended to retain the New River channel for the flow of the Chadwell spring and to collect all the springs issuing from the west bank of the valley between Amwell and Rye House, and lift them by steam-power about 10 to 15 feet into the New River; also to purchase the water-rights of the copious springs which now work Hoddesdon Mill and to collect those and others in the locality, and lift them also from 15 to 20 feet into the New River. Those sources, it has already been stated, may be calculated upon to yield the respective quantities of 4,500,000, 6,000,000 and 8,000,000 gallons per day, and out of the gravels and sands near Hoddesdon where the water is assumed to absorb and soak away into the sands under the London clay, a quantity of at least 4,500,000 may be estimated and could be lifted into the New River at a height of not more than 20 feet. A very much larger quantity from this source might possibly be obtained, but perhaps only effectively by longitudinal adits or driftways up the sides of the valley, works which are not contemplated in the present scheme. The collective quantity of all these strictly spring waters could be secured at a very small cost and would amount in quantity in dry seasons to about 23,000,000 gallons per day, a volume equal to the present flow in the New River, and therefore, notwithstanding the proposed abandonment of all further abstraction of water out of the Lea at Ware, the New River would remain in its present condition as to volume as far down as Enfield, where further works are suggested. Until within the last few years the New River in its circuitous course at Enfield flowed over the site of the proposed embankment for the large gravitation reservoir at Enfield Chase, but recent works for the cutting off the bends now place the channel at about 1½ miles distant, and at the point of the lower junction of the old course the present river measures 13 miles from Ware, and at the level of 93 feet above Trinity, making a difference of head between the New River and the top-water of the intended reservoir of 37 feet. It is proposed that so much of the old course as would unite the intended reservoir and present river shall be reinstated, and lined and covered for a means of supply from the reservoir into the river; and considering that the water would come from a large mass, cool and clear, it is thought advisable and intended in the scheme to enlarge and arch over the New River throughout, from the 13-mile junction to Hornsey. With regard to the manner of distributing the total daily yield of 47,000,000 from the store reservoirs and 23,000,000 gallons from the New River, in all 70,000,000, there are various modes of division that might be made, but considering that two companies have to be provided for, it is suggested that the East London Company should have 30,000,000 delivered over 24 hours, from filter-beds placed at the foot of the high-level reservoirs, and pipes from thence to Stamford Hill, delivering at the level of 112 feet into a service reservoir. The East London Company have a small reservoir at Stamford Hill, and I propose by means of a large main to deliver there at the level of 112 feet, and from thence the distribution over the whole of the East London district would be by gravitation, except perhaps a small area immediately in the vicinity of Stamford Hill itself. 30,000,000 gallons would be delivered at 112 feet, and no pumping would be necessary over the East London district, excepting the most elevated part, at Stamford Hill, which is in fact surrounded by the pipes of the New River Company. The highest surface level of the populated part of the East London district is not more than 45 feet above high water-mark. To the New River Company the remaining 40,000,000 should be allotted, who in addition would have a reserve at all times of their new chalk wells at Ware, which are said to be of considerable importance. Beyond the quantity of 70,000,000 gallons, I should also mention that if the proposed new works of the East London Company are carried out, bringing 10,000,000 gallons from the Thames, that would at once raise the quantity proposed by this scheme to an available volume of 80,000,000, as it would only be

R. W. Mylne, Esq.

6 June 1867.

necessary when extreme dry seasons occur to pump the 10,000,000 gallons. You will bear in mind that the quantity I have taken is the average of the two driest years known for 20 years; at other times there is one-fourth more volume of water than the quantity that I have calculated on.

4996. (*Chairman.*) What is the absolute quantity that you realize from the two sources?—47,000,000 gallons and 23,000,000 gallons, 70,000,000 altogether, leaving the New River Company's chalk wells as a reserve to add to that on extreme dry seasons, I do not take those wells into account, the yield of which is given in evidence, at about 5,000,000 gallons per day.

4997. The present supply of the New River and East London Companies is 37,000,000 gallons, is it not?—The present abstraction from the river Lea is 37,500,000.

4998. And you bring it up to 70,000,000?—Yes, including the Chadwell springs. To continue the explanation of the scheme a large-sized main is proposed to be laid from the high level reservoirs along the new line of railway about to be constructed. I should mention that there is an intended new line of railway, from Wood Green to Hertford, and it would pass across one of the gravitation Reservoirs and be at such a level as would not be at all interfered with. It is further proposed to have a 48-inch main leading direct to the New River Company's filtering station at Hornsey, and on its course to supply by gravitation the districts of Enfield, Edmonton, and Tottenham, places now in want of an improved supply. A series of filter beds are provided, but I consider that the water would not require half the filtering than is at present necessary.

4999. I suppose that the filter beds are similar to those sand filters which are at present used?—Yes, they are similar in construction to the East London and New River sand filter beds. (*The witness described the line of main to the Commissioners upon the map.*)

5000. What is the distance from those reservoirs to Hornsey?—About 7,300 yards. The branch mains are shown and I include in the estimate large mains for Edmonton and Tottenham. The main to Hornsey under the head of 70 feet would be equal to deliver more than the whole of the New River Company's present daily supply, and for temporary purposes would enable the existing channel of the New River to be emptied and re-constructed from Enfield to Hornsey in brickwork in a sound and efficient manner. The engine establishment for lifting the water into the high level reservoirs would be placed at the upper end of the gravitation reservoir near to the intended new railway and station, where if hereafter a further quantity of water were required a large amount could probably be drawn from the chalk in that particular locality. The chalk there comes near to the surface. Thirty-six feet is the difference of level between the two sets of reservoirs, and the upper ones are all connected by culverts. From the description I have given it will be seen that the East London Company would receive by gravitation from the high level reservoirs a minimum filtered dry season volume of 30,000,000 gallons, and the New River Company 40,000,000 gallons direct from the storage reservoirs through filter beds to their present establishment. The upper tributaries of the Lea will be stored and drawn upon to produce the quantity nearly to their utmost in seasons of such extraordinary drought as occurred in the years 1863 and 1864, but a sufficient margin is left even at such a dry period for navigable and valley purposes, and within a short distance below the points of diversion springs and streams, with the rivers Ash and Stort, will augment the volume to the extent of their present flow. The advantages to the East London Company are that the water would be drawn from a purer source than at their present intake, being freed from the valley drainage and future cost of diverting it, and obtaining a gravitation supply in lieu of pumping, and the New River Company would have an increased and improved supply freeing them from the necessity for many years to come of looking to the river Thames or other distant sources, but confining their endeavours to within the legitimate and as yet unutilized valley waters of the River Lea.

5001. You have generally described your scheme by which I understand you provide about 70,000,000 gallons per diem?—Yes.

5002. Will you now state the cost of that scheme?—The cost of carrying out that scheme apart from the question of compensating by steam power such of the mills as would be affected by the abstraction, would be 1,250,000*l.*

5003. Does that cost include the purchase of land, easement, and severance?—Yes, it includes the purchase of land, easement, severance, and construction of works.

5004. Does it include the cost of the pumps and engine houses?—Yes, engine-houses, pumps, and everything.

5005. What would be the annual cost of engine power?—The cost of pumping at the engine stations at Enfield Chase to raise the water from the gravitation to the high level reservoirs, and at the Rye House district for lifting the collective springs into the New River will be 6500*l.* per annum inclusive of complete staff.

5006. Your scheme generally is a scheme which will double the supply of the New River and the East London Water Companies?—It will nearly double the quantity taken by those companies last year from the Lea.

5007. At an expense of 1,250,000*l.*?—Yes.

5008. That includes compensation, the purchase of land, easement, severance, and every question of that kind, and also the expense of erecting steam-engines, pumps, and all necessary machinery?—Yes.

5009. And of course it involves an annual charge for pumping?—Yes, and the pumping at present carried on by the East London Company would be wholly superseded, which recently has been given in evidence as representing in coal 6,000 tons per annum lifting 20,000,000 gallons per day to an average height of 112 feet above Trinity high-water mark.

5010. And this cost which you have described is to produce an additional quantity of 37,000,000 gallons?—An additional quantity of 28,000,000 gallons.

5011. Where you now supply 42,000,000 gallons you propose to supply 28,000,000 more gallons?—Yes.

5012. So that practically for London your scheme proposes to add 28,000,000 gallons at a cost of 1,250,000*l.*?—Yes; it adds 28,000,000 gallons, and the cost is to obtain that additional quantity and for works to convey the further quantity of 42,000,000 from higher points in the valley, and the collection of a large number of springs which now run into and mix with the Lea drainage; the whole 70,000,000 being conveyed in covered channels to London.

5013. And that is simply to bring the water and discharge it into the plant of the two companies; it includes no expense for distributing mains and so on, or for internal pumping for the purpose of equalizing the pressure in the district itself?—It includes no expense for distributing mains; that allotted to the New River Company would be delivered into their present establishment at Hornsey, where they would deal with it in any form they thought advisable; that to the East London Company would go direct into their mains, and their present pumping will be unnecessary.

5014. What is the character of the water generally?—The same character as the water now supplying the New River Company with the improvement of the diversion of the sewege of those towns on the rivers that have been specially mentioned; it would be of about the same degree of hardness. By impounding the freshes it would rather lessen the average hardness of the water.

5015. This scheme of yours would involve the necessity of some considerable outlay to divert the sewage and other things which find their way into those streams?—I do not suppose any works of diversion

above Hertford would be necessary particularly if the river is likely to be put under a new Conservancy Commission, with extensive powers to prevent pollution.

5016. (*Mr. Prestwich.*) If I understand you rightly, you would intercept the waters of the tributaries of the river Lea at a height of about 150 feet above Trinity high water?—No, it is from about 133 to 140 feet.

5017. How do you then get those waters into the reservoirs at 166 feet of height?—There is to be pumping from the gravitation reservoirs into the higher ones at 166 feet; the gravitation reservoirs are 130 feet with 3 feet of fall from the Lea into them.

5018. Do you propose to have any collecting reservoirs on the Lea and the Mimram?—No.

5019. Your scheme would be in fact diverting the present flow of those streams to a high level reservoir near London?—Yes, just so; and the scheme avoids the drainage of the river Stort and the Ash.

5020. By so doing would you not very materially interfere with the flow of the Lea below Hertford?—For mill purposes I should.

5021. You propose to take from those tributaries 40,000,000 gallons?—Yes, very nearly the whole in the very driest seasons.

5022. Should you take a uniform quantity from each of those tributaries?—In times of drought very nearly the whole would be taken. When the freshes come down they would pass on through the tunnel; on the river Rib the freshes would come down into the large reservoir proposed to be made below Standon.

5023. How many days' supply do you propose to provide for in all those reservoirs?—The total quantity of the six reservoirs on Enfield Chase is 2,640,000,000 gallons.

5024. That is sufficient for how many days' supply?—That would be 63 days' storage on Enfield Chase, with a further storage on the river Rib.

5025. What grounds have you for supposing that the streams which you intercept will at those points furnish that quantity?—From having gone carefully into the gaugings at Feilde's weir, which have been placed at my disposal, and from them forming an opinion on the proportional discharge.

5026. Of course a large portion of the water which passes Feilde's weir is received between the points where you intercept the water and Feilde's weir?—Yes.

5027. Are not there numerous springs which issue between Hertford and Feilde's weir?—Yes, and the rivers Stort and the Ash. Taking the quantity at 66,000,000 gallons at Feilde's weir from the gaugings, it is calculated, from various sources of information, that there will be 43,000,000 gallons collectable from the 246 square mile area, but assuming that the yield was taken on the proportion of the entire area due to Feilde's weir it would give 40,000,000 gallons.

5028. Have you any means of determining the quantity of water which issues in the form of springs between the point where you intercept the streams and Feilde's weir?—That is given in detail from the gaugings which are given in a Parliamentary report of Mr. Simpson and others, and from which those proportions are derived. One of the leading features of test is at the point of the New River intake, where the minimum flow under present conditions, without impounding, may be taken at 3,000 cubic feet per minute, or about 27,000,000 gallons per diem.

5029. Then in your scheme the actual gaugings the streams rather than rainfall is the important element, is it not?—Yes. I have based my calculations chiefly on Mr. Simpson's and other gaugings, all of which have been printed, and are given in the Parliamentary papers in the evidence of 1851 and 1852.

5030. The gravitation reservoirs which you propose to construct in Enfield Chase are to be upon the London clay?—Yes.

5031. Have you made borings in the clay to ascertain its depth at this point?—No, I have made no borings.

5032. In the upper part your reservoirs I see approach very closely upon the chalk, and upon the sands beneath the London clay?—Yes, the upper end of two of the high-level reservoirs.

5033. Would it be possible to construct reservoirs at that level with such a sub-stratum as that?—I think so. I have looked into that point very carefully, and where the embankments are placed the chalk is at a considerable depth from the surface, and the clay overlying is of some thickness.

5034. But the upper part of your reservoir touches upon the sand beneath the London clay?—It just touches it, and that part would be puddled; the extent of puddle would perhaps be of two or three acres.

5035. You propose to establish apparently some collecting reservoirs upon the Rib, above West Mill and below Buntingford?—Yes.

5036. What is the nature of the soil there?—I have carefully examined it. There were borings made some years since on the Rib, and I am of opinion that sound reservoirs can be formed, considering that the maximum depth of water will not be more than 20 feet.

5037. Is it not chiefly gravel overlying chalk?—No; there is very strong brick earth and loam of a thickness of from 6 to 7 feet, and in some places 10 feet, and the clay in my judgment will hold water.

5038. Is there not in that district a dark clay lying upon the tops of the hills?—Yes, but you are alluding to the Boulder clay, I suppose, which lies upon the tops of the hills.

5039. But the clay you refer to is found in the valley?—Yes, in a particular part of the valley.

5040. And this clay forms part of the drift of the valley?—It is separated from the clays on the top of the hills; it is wholly drift clay, forming strong brick earth.

5041. Is there any great thickness of that clay?—I have just mentioned that there is from 6 to 7 feet, and in many places 9 to 10 feet.

5042. Is it local?—It is continuous over that particular part where the reservoirs are proposed; it varies over the district very much.

5043. Is there any gravel above or below that clay?—I do not know of any extent of gravel except here and there there is a little gravel below it.

5044. When you pass through these 8 or 10 feet of clay, what do you reach?—Chiefly chalk.

5045. The total quantity which you propose to deliver from your several sources would be 70,000,000 gallons?—Yes.

5046. Notwithstanding that, you have just stated that the flow over the Feilde's weir does not exceed 66,000,000?—Yes.

5047. How do you account for the difference?—By impounding; by catching the freshes and collecting springs below.

5048. Of what period is that 66,000,000, the average?—66,000,000 is the average of the two driest years 1863 and 1864 at Feilde's weir, the lowest that has been known.

5049. Have you not calculated upon more than that average yearly?—No, I take that as the datum, and that being the average I can ascertain what storage room is necessary to give uniformly 66,000,000 all the year round.

5050. I understood you to say 70,000,000 all the year round?—I am afraid we are not alluding to the same point. At Feilde's weir the average yield of the Lea area in 1863 and 1864 was 66,000,000, and by storing the freshes it would give that volume. I have not gone into how much storage would be necessary there, as I do not propose to store at Feilde's weir, but to store at a higher point on the river where the proportion is 43,000,000 as against 66,000,000 of flow. The Ash and the Stort are left in their present condition, and are not included in the scheme.

5051. (*Mr. Harrison.*) This is a scheme which of

R. W. Mylne, Esq.

6 June 1867.

course could only be carried out by the existing water companies?—I presume so; the water rights belong to the existing companies.

5052. Have you submitted it at all to them, or is it now brought forward for the first time?—This is the first time it has been suggested. I only took the matter up recently in consequence of the evidence and report of the Pollution of Rivers Commission on the Lea, stating that there were no other areas where impounding gravitation reservoirs could be made on the London clay in the Lea basin, except below Broxbourne.

5053. Irrespective of the question of the mode of dealing with it, your knowledge of the Lea leads you to the conclusion that it is practicable by some means or other to obtain altogether between the two companies something like 70,000,000 gallons?—Yes, I consider so decidedly, which quantity would be a minimum on the driest years, and would be derived in part from a drainage area of 253 square miles, from tunnel interceptings, and from the collection of springs at Chadwell, Amwell, Rye House, and Hoddesdon.

5054. (*Mr. Prestwich.*) Is not the flow of water in the river Lea generally very uniform?—Yes, in the upper portions of the Lea it is even much more so in proportion per square mile than the flow at Feilde's weir.

The following Table of comparative supply was appended to the Waterworks District Map, exhibited by the witness:

North of the Thames.

NEW RIVER and EAST LONDON.

	1853.	1866.
Average daily supply in gallons -	30,135,753	42,277,769
Houses, manufactories, &c. - -	159,983*	204,939

* Including Hampstead.

CHELSEA, WEST MIDDLESEX, and GRAND JUNCTION.

	1853.	1866.
Average daily supply in gallons -	15,748,281	24,986,373
Houses, manufactories, &c. - -	65,152	90,302

South of the Thames.

SOUTHWARK AND VAUXHALL and LAMBETH.

	1853.	1866.
Average daily supply in gallons -	12,870,324	21,452,000
Houses, manufactories, &c. - -	66,787	111,183

Total average daily supply of the above seven waterworks companies 88,716,142 gallons.

The witness withdrew.

T. Hawksley, Esq.

THOMAS HAWKSLEY, Esq., further examined.

5055. (*Chairman.*) We have troubled you again in consequence of our instructions being somewhat limited when we had the pleasure of receiving your evidence on the previous occasion. Those instructions have now been so enlarged as to enable us to ask you some few questions with respect to the Thames basin generally, or rather the Thames watershed. When you were here before you gave us your opinion of the several schemes that have been suggested by Mr. Bateman, Mr. Hemans, and so on, can you now state generally whether there is capacity in the Thames watershed to supply a sufficient quantity of water for the metropolis?—I think so.

5056. You mentioned that the drainage area was 3,656 square miles, and the population 235·3 to the square mile?—Yes, including the rural population, that is the number very accurately taken out.

5057. You are aware, I presume, that the water companies have power to take 100,000,000 gallons per diem from the Thames, and that they are now taking but one moiety of that?—Yes, about that, rather under, I should think; on the average of the year probably not more than from 40,000,000 to 45,000,000 gallons.

5058. As an engineer well acquainted with the river, are you of opinion that they might take the maximum quantity which they are entitled to do, under their several Acts of Parliament, without injury to the river?—Yes, certainly.

5059. Without any interference with the navigation?—Yes, without any injury to the river at all. Below Teddington weir the river becomes tidal, and it receives consequently not precisely sea water, but the water that is thrown back by the sea, which is equivalent to receiving sea water, consequently it is not dependent upon the upland water entirely. Then again, it is necessary to bear in mind that the water is not lost to the Thames, it is only lost to a particular length of the Thames, it all comes in again at London, so that there is only the distance between Teddington and the metropolis in which the upland water is lost.

5060. Except that which is carried by the main culvert down to Barking?—I call that the metropolis. All will go down to Barking as a rule, during all the dry weather flow of the sewers, and consequently all the water taken from the Thames by the water companies will be carried down to Barking in the dry weather. There is no question that it all goes there, and therefore the intermediate part of the river is deprived not exactly of that quantity of water, but of a certain portion of it; that is to say, it occasions the run of the tide upwards to be longer, and the run of the tide downwards to be shorter in point of time, but the river itself flows up by this longer uprun of the tide practically to the same level, and if you were to reduce it to a matter of calculation you would not find it would make many inches difference, perhaps not more than two or three inches difference.

5061. So far as the river is concerned, up to Teddington, where the tidal influence ceases, you think that the abstraction of 100,000,000 gallons would not seriously interfere with the scour of the river below that point?—I do not think it would interfere at all with it; and for this reason, that the upland water of the Thames in its ordinary state has little or no influence upon the scour. In fact it is chiefly when in flood that it has an influence on the scour, and the floods of the Thames are so enormous that practically the quantity taken by the water companies then disappears from the calculation altogether. The maximum flood in the Thames is about 20,000,000,000 or 25,000,000,000 gallons in a day; that is a flood which occurs only once in a considerable number of years, not a very ordinary flood.

5062. What is the maximum height of the water line as raised by means of the floods?—I forget without reference; it is, I think, 10 or 12 feet.

5063. Mr. Simpson gave it as 10 feet 11 inches?—That may be; I do not know what Mr. Simpson's evidence has been.

5064. But in your judgment that would be likely?—Yes, that is very likely.

5065. Do you think that a larger quantity than the statutory limit might be taken from the Thames without any storing process?—Yes, I have no doubt about it.

5066. To what extent in your judgment?—I think that no sensible harm would be done either to the navigation or to the proprietors of the riparian property if that quantity were increased to double the statutory amount. If you took half the lowest volume of the Thames (and the lowest volume only lasts for a very short time) I do not believe that it would have any sensible influence.

5067. I understand that the lowest flow over that part of the river of which Mr. Simpson has taken careful sections, according to the gauging of the river

at that point, is 380,000,000 gallons?—My calculation is 360,000,000 gallons.

5068. Mr. Simpson stated that the average flow would be about 700,000,000 gallons, do you agree with that?—The average flow of three consecutive dry years is I believe about 6 inches of rainfall, and that would give nearly 900,000,000 gallons; that, of course, includes the floods of those years, although they are small; perhaps those Mr. Simpson threw out of the amount, it is I believe as nearly as possible 900,000,000 gallons on the average of those three consecutive dry years. I am giving summer and winter, and taking the whole year's flow. It is about 1,500,000,000 gallons on the average of all years. 5 inches run off in a very dry year, and about 10 inches on the average of all years.

5069. Are you of opinion that 150,000,000 gallons per diem might be abstracted from the river without injury to the river itself?—Yes, certainly, at the point where the companies take their supply—I do not mean in the tidal part—there you might take a much larger quantity without injury, but of course if you went higher up the river where there is no tide to fill up the void it would have a different effect. Supposing you went above Windsor, then of course it would very much diminish the flow of the Thames through Windsor Park, but it has very little effect below Teddington Lock, because the vacuity, or rather that which would be the vacuity if there were no tidal water, is filled up by the tide.

5070. Then the injury, if any, would simply be between Teddington Lock and the point where they take their supply?—Yes, but that is a pond, and therefore it would be of very little consequence.

5071. But supposing the demand of the metropolis exceeds say 150,000,000 gallons per diem, a larger quantity might be obtained from the Thames by impounding the storm water?—Yes, that must be taken with reference to the three consecutively dry years and not with reference to the average of the whole. You cannot deal with the average of the whole in any way, and therefore what you would have to do would be to impound the floods or a quantity equivalent to the floods of the years in which only 900,000,000 gallons was running past Teddington weir, instead of the floods of the wet years.

5072. But there are points in the Thames water shed that are peculiarly suited for the formation of a reservoir above Oxford, are there not?—They are very well situated as regards water tightness, being chiefly upon clay, but I believe there would be almost in any situation a considerable amount of excavation to be made and that is a most expensive process. We never like to make storage reservoirs by excavation. We always make them by embankments if possible.

5073. You mean excavation to get down into the clay?—Yes; to make a hole in the ground for the reception of the water is a very expensive process. To make it by embankments would be very much cheaper, but then you would spread the water out and perhaps rather overlap the clay in some cases, and you might, in that case get into more open strata, whether of the chalk or the oolites.

5074. Are you aware that the Thames Conservancy Board are now clothed with power to call upon all the local authorities on the banks of the river up to and including Oxford to divert their sewage and other polluting matter from finding its way into the river?—Yes.

5075. Of course the river would be greatly improved if that principle were adopted uniformily up the river?—The river would be very much improved near the towns themselves, but at considerable distances from the towns it would have no effect whatever, because all those matters are exceedingly decomposable in the presence of oxygen and become decomposed entirely by oxydisation. There is no such thing as a particle of fæcal matter put into the Thames at Oxford finding its way down to Hampton Court. It is all burnt up in fact by the combustion set up by the oxygen. There are three kinds of decomposition; there is the decomposition by oxydisation which is perfectly harmless, then everything becomes as sweet as it was in its original condition, because those animal matters are constituted of perfectly pure elements, and it is only the association which is unpleasant, and anything which disassociates the elements returns them to their original condition as pure as ever they were. The hydrogen which comes off from those matters after its liberation by the oxydisation is just as pure as it was in its original state, and so with regard to the other elements. As I was observing there are three conditions of decomposition. One is by oxydisation which is perfectly inoccuous and is a natural process of purification, the next is by putrefaction, which is excessively offensive, and then there is another species of decomposition by fermentation. When any of these sewage matters are put into running water which contains a vast amount of oxygen, as much as 40 or 50 gallons of oxygen in 1,000 gallons of water, it immediately attacks them and they become gradually decomposed and resolved into their original elements, or are re-associated in only perfectly pure states, nothing offensive remaining, and that has been going on ever since the creation of the world, the very Atlantic itself would ere this have been a cesspool if it were not for that process.

5076. What quantity of water, as compared with the volume of sewage, is necessary for the purpose of breaking up into its original elements the sewage which has been discharged into it?—Generally about 20 to 1. If the water flows rapidly and is very much disturbed, so as to be continually receiving fresh oxygen, a smaller quantity, even 12 to 1, will effect the process; if it proceeds very tardily it may take a little more; but usually 20 to 1 is perfectly abundant. I could give you very remarkable instances. Take Sheffield: nothing can be fouler probably than the state of the water at Sheffield, whereas if you go down to Doncaster the water is supplied by the waterworks and is actually drunk in the town. I do not, however, say that it is a desirable thing.

5077. How many miles is Doncaster below Sheffield?—About 20 miles.

5078. Is it a rapid running stream?—No, it is not rapid in summer. In point of fact it is controlled by the weirs set up for the navigation. But take the river Irwell leaving Manchester, receiving the Irk, the Matlock, and all the refuse of the manufacturing population for a great many miles; when it travels down only eight or nine miles to Warrington it is perfectly changed, it ceases, or nearly ceases, in that short distance to be an offensive river. I do not say that it has become all that it ought to be by any means, because the distance is not sufficient, and the flow is not rapid enough. The river is canalised, which prevents its flowing with all the rapidity it ought to have.

5079. You remember, do you not, the original condition of the river at Leicester after receiving all the sewage of the town into it?—Yes, perfectly well. I happened to be the engineer at Loughborough and also at Leicester. I made the waterworks at Leicester, and I advised the sewage works at Loughborough, and I also was called in to design waterworks for Loughborough, and I had on those occasions to take particular notice of the state of the river at all times, both at Leicester and at Loughborough, Loughborough being about 12 miles below Leicester. At Leicester the water was as black as this ink. I do not mean to say that it was absolutely so thick, but looking at it in a mass it was as black as ink,—nothing would live in it, and the smell was abominable,—but by the time it got to Loughborough it was entirely restored to its pristine condition. You could stand on the bridge there and see the fish swimming amongst the beautiful reedy and other plants growing in the water just as in the purest stream. You could see every pebble at the bottom. That is an instance of the effect of oxydisation.

5080. The water has symptoms of returning purity, has it not, within four miles of Leicester?—Yes, but not to the same extent as at Loughborough. The

T. Hawksley, Esq.

6 June 1867.

water was perceptibly impure at the driest period of the year down as far as Barrow. It could be just perceived there, but at Loughborough it was perfectly restored.

5081. Notwithstanding that law of nature, you would as a matter of prudence desire to have all sewage excluded from rivers, especially from rivers which are the source of supply of water for domestic purposes?—Yes. I would myself do a great deal to comply with the taste and even the prejudices of the people. I know, of course, there is nothing in all those startling statements that are made about disease travelling in water great distances and so on. I say there is no foundation for them in fact, but there are nevertheless strong and natural convictions on this subject which ought not to be disregarded.

5082. You are not able to speak as to whether disease in germ is carried from one point to another in water?—I am able to speak to it in this way. In the year 1848 or 1849 the cholera invaded the towns of what is called the Black Country, such as Bilston, Willenhall, Wolverhampton, Walsall, very frightfully, so much so that the people encamped out in the open air. I saw them myself. Those towns are all situated upon the river Tame, a very small river, which has its origin near Bilston; it flows down to Birmingham, a course of not many miles, tortuously perhaps twenty, but directly I suppose not more than a dozen. The water of that river was supplied to Birmingham, and yet there was not a case of cholera in Birmingham, excepting one, which was imported. Whilst in the adjacent city of Coventry, supplied by artesian and other springs, into which no sewage water entered, cholera was very rife and very fatal. I have been amongst cholera all my practical life. I believe I was concerned in building the very first large cholera hospital that was erected in England, in 1831. I have been amongst cholera abroad, when it has been in its worst phase, and I have been called in to almost every town in England where there has been any serious attack of cholera, because there has always been something to be done either with the water or the sewage, or something of that kind, and I can state most decidedly that this doctrine of the transmission of cholera and other diseases in the way that has been spoken of is utterly unfounded. Cholera is a very remarkable disease, and inscrutable as to its origin, but exceedingly rapidly propagated by infection, especially when the disease assumes an epidemic character. In 1853 or 1854 the cholera made an attack upon Newcastle, and it was very fatal there, but there was no cholera at Sunderland. Those two towns are about 12 miles apart in a direct line. Sunderland and Monkwearmouth are practically one town, just as Gateshead and Newcastle are another. There was no cholera at Sunderland excepting one or two imported cases, but on other occasions there had been a great amount of cholera at Sunderland, and on those occasions there had been comparatively little at Newcastle, although it had never been free. On that occasion (and I am speaking of towns that I have been connected with) after the cholera had done its work at Newcastle, it suddenly jumped over to Bishop's Auckland and settled down there, and was very destructive, then it passed down the river still omitting Sunderland, and returned upon Durham, but although those two places are upon the river Wear, Sunderland, which is also upon the river Wear below them, was never attacked. Take Copenhagen also as an example. The cholera twice visited the Baltic, without touching Copenhagen, although Copenhagen was then the worst sewered town perhaps in the world, all the night soil and garbage was thrown out on the little Island called Hamager adjacent to the town, and the stench from that island pervaded the whole city at night in hot weather. But in 1853 the cholera settled down there like a cloud, not attacking many other places in the Baltic, which it had visited before, and before I left more than 4,000 people had died. No change had occurred in the state of the city or of its water supply on the third visit of the cholera to the Baltic from the state which had prevailed on the first and second visitations. Then again to show that the water has nothing necessarily to do with it, cholera always follows a certain track, it has its origin in the East Indies, it travels usually through Russia sometimes for two or three years before it reaches England, and it passes always against the prevailing wind. The prevailing wind is westerly, but the cholera comes with the march of the Marmot from place to place almost directly in opposition to it. I am persuaded, and all my experience shows it, that those things to which it has become usual to refer it have nothing to do with the cholera, and that the cholera has nothing to do with them. The cholera germ is a thing of the imagination, inasmuch as nobody has seen it or has been able to watch its development or effects.

5083. Having regard to the capacity of the Thames watershed to yield a sufficient supply for the metropolis, (and when this system or purification is completed, whether for the sake of removing prejudice or any other purpose, to get rid of filth at all events the water must be improved,) you are of opinion that there is no necessity to seek a supply of water from a distance from the metropolis?—Certainly not. You have very fine water surrounding London in all directions, and it only wants utilising.

5084. You think that there is a sufficient quantity of water to supply the whole of the metropolis, independently of the New River, the East London and all the auxiliary aids which London has for water supply?—Yes, there is an immense basin and storehouse of water in the chalk, extending for miles around London, which might if hereafter necessary (it certainly is not necessary now) be resorted to.

5085. (*Mr. Harrison.*) You have been consulted, I daresay, by every water company in London?—I believe I have.

5086. For how many do you act directly as consulting engineer?—I have been engaged in all of the water inquiries from 1851 down to the present time. Occasionally I am called in professionally, but I have been consulted separately by a good many of them.

5087. In every individual case of a London Water Companies Bill, I dare say you have been consulted?—Yes, I dare say I have, or nearly so, except where they have gone merely for capital, I am not interested in that.

5088. Would you state your opinion as to what is the probable necessity per head of a population like London?—It does not exceed 25 gallons for all purposes.

5089.—Should you consider that taking 30 gallons was quite a safe calculation?—Yes, 30 gallons is a very wide calculation.

5090. That is rather below the present consumption of London?—No, I think the present consumption is 28 gallons. The calculations of the water companies are made very consistently, but they are calculated for engine purposes chiefly. They calculate usually by the displacement of the pumps, without making any allowance for the loss by valves and other causes. When we compare works of that kind with gravitation works, with which they frequently have to be compared, we take off from the pumping works about 10 per cent. to bring them to the level of gravitation works.

5091. Any calculations of the supply of London based upon 30 gallons per head for all purposes, would be an abundant and safe calculation?—Yes, more than enough.

5092. Looking forward to any alteration in the habits of the people which might induce them to consume more?—Yes, that takes all trades, all water-closets, stables, incidental causes of consumption, baths, and all household consumption and street watering.

5093. Assuming that reservoirs were made, and, as you say, you would not do them by excavation, it might be necessary, might it not, to bring the conducting conduits several miles higher up the river, to bring the water off and to fill those reservoirs in that

form ?—That might or might not be, it would depend upon the declivity of the particular watercourse.

5094. If it became necessary in after years to make any compensating reservoirs for the obstruction of a larger quantity of water, no difficulty would exist in finding a place or places upon the Thames to carry out such works ?—No certainly not.

5095. Do you consider that 200,000,000 gallons a day might be taken from above Teddington if you were ever called upon to supply that amount ?—Yes, I do.

5096. And that any question of possible damage might be met by such compensating reservoirs ?—Yes, certainly. I am not sure that even 200,000,000 gallons could not be taken without occasioning any sensible damage. Of course there would be a theoretical damage. You would have the lower waters running higher up than they do now ; I mean that by the operation of the tide the lower and the upper waters meet to fill up this cavity, and of course if you abstract from the upper waters, the lower waters will run so much higher up. But there will be a great improvement, and it is necessary to mention it, by what the Metropolitan Board of Works are doing. The training of the river through London will have an effect quite different from what many persons suppose ; it will have the effect of conducting the water up towards Teddington much more freely than it has been conducted heretofore, and it will really be an improvement. If the river be trained through London, about 750 feet wide, there will be so considerable a scour that its bed will be lowered, and there will be a very much larger quantity of water passing up than heretofore.

5097. (*Mr. Harrison.*) Looking at the largely increasing population on the banks of the Thames, unless some such provision had been made as that which was passed by the Act of last session giving power to the Thames Conservancy Board, in a short time the pollution of the Thames might have been such as to render all the water which we are taking from Hampton exceedingly bad ?—There is not a great population in the valley of the Thames ; above Hampton it is very small, and the town population, with the exception of Reading, is not sensibly increasing. Reading is not a large place ; it has under 30,000 inhabitants.

5098. I think you stated before your opinion as to the relative values of soft water and hard water ?—Yes ; soft water collected from the surface is very valuable in certain manufacturing districts, but in non-manufacturing districts chalk water is more valuable because it is much more agreeable. It is necessary while upon that subject to explain a matter which is very little understood, that is, with regard to the consumption of soap, upon which the errors of calculation are enormous. People suppose that all water used for detergent purposes is practically saturated with the soap, whereas it is not so as respects hard water. For washing in the morning, you take a gallon of water, half a gallon for washing the hands, and another half gallon afterwards for washing the face, you do not consume with the soap more than half a pint of water at each operation, indeed not so much as half a pint, for what you do is this ; you do not begin to make the whole quantity of water into a lather, you moisten your hands, take the water into your hand, and the soap upon it, and you rub it about till you get a lather, and you merely operate upon the quantity of water which is in your hands, then you rub it round, so as to take the dirt off your hands, and then you rinse your hands in the remainder of the water. That water is not saturated with the soap at all ; the soap has nothing to do with it, except that you use it for rinsing purposes, and you deal with your face in the same way ; and the washerwoman deals with her clothes in the same way ; she dips the clothes in the water, she takes them out, and rubs the soap on them, and then rubs the clothes together with her hands, and the small quantity of water that saturates the clothes is all that is dealt with by the soap, or nearly all ; but chemists and others who make grave calculations upon these subjects suppose the whole bulk of water to be saturated with the soap, and that is the great mistake they make. If you were to calculate the number of grains of salts acting upon the soap in the whole bulk of the water as they do, and suppose all that to operate upon the soap, to decompose it, you get to a vast calculation at once, the result of which is entirely fallacious : nevertheless of two waters equally good in other respects, I should select the softer. The improved supply to Paris has been brought from remote districts of the chalk formation expressly because, (1) it is salubrious ; (2) it is limpid ; (3) it is brisk. Whilst the softer waters flowing from the surface of the granite were rejected because they did not possess these properties in equal degree.

5099. (*Chairman.*) That is not the mode of calculation adopted by Mr. Bateman, is it ?—I am speaking of chemists and the great mistakes which are made in scientific books upon the subject of the saving of soap. The fact is, I am stating very much in excess the quantity when I say that a pint out of a gallon is saturated. You do not usually saturate anything like that amount of water with the soap.

5100. Your attention, as that of every other engineer, has been given to the question of constant supply ; do you consider it an important question for sanitary purposes that the poor people in all towns should have an abundant supply of water in whatever form it should be given ?—They should have an abundant and constant supply of water, but they ought to be prevented by proper means from wasting the water.

5101. Still you look upon it as an essential point that the poor people ought to have an abundant supply of water ?—No doubt ; but that is mainly a landlords question. I do not believe that there is any water company either in London or anywhere else that would not give a constant or unlimited supply of water if the landlords would only adopt those means for putting the fittings in proper order which are adopted in other towns where the constant supply is a success ; but if people perversely say, We will have the water constantly on, but we will not submit to proper supervision, and we will not bear the expense of proper apparatus, then it simply becomes impossible. And hitherto that has been the state of things in London.

5102. In many of the towns, I believe, where they have adopted the Health of Towns Act, have they not the power of shutting up houses that are considered to be in an unhealthy state ?—No, not unless they are in such a deplorable state that they are not fit for human habitation ; that is the expression in the Act.

5103. Would not the same words almost apply to a house which had no supply of water ?—No, because they may go somewhere else and get their water and carry it in. The house may be a very good house, as good as my house, and it would be quite fit for human habitation, and yet there might be no immediate water supply to it.

5104. Do you think that it would be an unfair thing upon the landlord to compel him to find the means of supplying water for his houses ?—I do not think it would be unfair. You are now speaking, of course, of houses below a certain rental, or houses which are let out in apartments to different tenants.

5105. Their being supplied with a sufficiency of water does not necessitate a constant supply night and day ?—No. A constant supply, with proper regulation and proper supervision, takes less water than an uncontrolled intermittent supply ; but then you must have that regulation and supervision, and if the public will not submit to the expense and will not submit to the inspection, nothing can be done for them ; but if the Legislature choose to empower the companies to make it compulsory upon the landlords, through some other authority, to put everything in a proper state of repair, and keep things in that proper state of repair, there is no reason at all why the constant supply should not be granted to-morrow. I do not think that there is any company in London that would think of resisting it ; but they are all in a state of alarm now, because

T. Hawksley, Esq.

6 June 1867.

they know perfectly well that if they were to turn on the constant supply to-morrow, probably three-fourths of the houses in London would receive no water. I should not get any water myself, it would all be draughted off into the lower districts, and run away in waste. But that is not so in the towns where there is a constant supply, and where those powers are conceded and where they are properly acted upon.

5106. I gather generally from your experience of this matter that you consider the Thames capable of supplying, taking it in connection with the Lea, any possible quantity that the population of London could require, and also that the quality of the water would be in your opinion unexceptionable?—Certainly.

5107. Therefore you would not consider necessary to go beyond that which you have at your own door for supplying this metropolis?—I should not.

5108. You also expressed an opinion, did you not, that if you had the choice of soft water or of chalk water you would hesitate in the selection which you would make?—I should not hesitate at all if I found as is almost invariably the case that the soft water were a tinted water, that is to say if it had any preceptible colouring of brown or yellow in it. All soft waters, or nearly all soft waters, are tinted unless they come from perfectly barren rocks or springs, and it is because of their power to take into solution such a vast amount of colouring matter, from the peat and heather, and mosses of various kinds in the neighbourhood where those waters proceed from, that they do practically always become tinted. Water of that kind would never be tolerated in London. That subject has been the cause of the most angry feelings and quarrels extending over many years and embittering man against man in a great many towns which I could mention, and particularly in Liverpool. Liverpool is in a manufacturing country, but it is not a manufacturing town, and the people of Liverpool delight in clear, bright, sparkling water, and do not value soft water that is tinted, and they will not have it if they can avoid it, whereas if you go to another town, a manufacturing town, such a place as Bolton for instance, amongst the bleachers or calico printers, or people of that kind, they would not have hard water, their trades and the wealth and comfort of the population are dependent upon the presence of soft water, there they would not have the water which pleases the Liverpool people, they go to the hills and bring in the softer brown water.

5109. (*Mr. Prestwich.*) Do you know whether there is not a difference of opinion even amongst dyers and calico printers with regard to the use of soft and moderately hard water?—I do not think that with regard to dyers and calico printers there is any difference of opinion, because the salts usually contained in hard waters affect and decompose some of their dye stuffs, and sometimes interfere with the brilliancy of the colours, and of course they are anxious to get water which contains as little as possible of those dissolved salts.

5110. There is greater economy, is there not, in the use of material where they have soft water?—It is not merely economy in the use of material, but it is because in calico printing for instance they want with respect to a good many colours to have very great brilliancy, it is in that respect that the French excel so much, their colours are very clear and brilliant. Some of the salts which are contained in many hard waters prevent that brilliancy of colours, and of course they are very anxious to avoid those waters.

5111. Do not some of the reds come out more brilliantly under the action of moderately hard waters?—Yes, that is as to some processes of dyeing. The rinsing process, for instance, after printing is one which they like to have performed with water that is entirely uncoloured, because a brown water stains the whites in cotton printing particularly. In cotton printing the cotton itself is capable of entering into a chemical union with the brown colouring matter contained in the water, and therefore, although it may not take a perceptible brown, the brilliancy of the white is destroyed, hence they want spring water as well as surface water. The calico printers use two waters, they use the water stored from the moors for their general purposes and then they try to get soft spring water, not hard spring water, but if possible soft spring water without colour, for finishing, as they call it.

5112. You are probably aware that some experiments were made in France at Lyons some years ago by Du Pasquier which give some very curious results with regard to the use of hard and soft water, showing in many cases the advantage of hard water?—Yes, but that is only in reference to a particular species of dyeing, particular colours that would be liable to be affected by the solvent property of soft water.

5113. With regard to the navigation of the Thames between Kew and Teddington I understand that the people on the lower parts of the river complain that they can no longer load their barges to the same extent that they could formerly. To what should you attribute that?—That is chiefly attributable to the removal of old London Bridge which operated as a dam and prevented the tide from receding as far out as it now does.

5114. But I understand that this complaint applied to a more recent period than that?—I should think that those complaints must arise from very vague observations and probably they are prejudices. I do not think it arises from the abstraction of water by the water companies, which is quite too small to produce any sensible effect. The river is very materially affected by the removal of old London Bridge The fall, if I recollect right, at old London Bridge was between 4 and 5 feet, and that of course always prevented the tide from receding as far as it recedes now. If the process of dredging and scouring goes on the effect of it will be that the river will be left comparatively dry at the upper end of the tidal range when the tide is out, and on the other hand the water will flow in much faster and will rise higher when the tide is in. You will have a greater variation at Teddington Lock say, or at Richmond, or any of those upper levels; the tide will rise higher and will fall lower.

5115. You would attribute nothing to the abstraction of the water?—Nothing sensible; nothing that they can found upon I am sure.

5116. Could you suggest any mode of meeting the requirements of supplying the poorer class of dwellings with a more constant supply of water without having the water delivered into each house or without having the supply constantly?—So far as regards houses which are in groups there is no difficulty because it is only necessary to have a sufficient cistern; one cistern would do for the whole; but with regard to houses not in groups and not supplied by one landlord, of course there must be a cistern to each house.

5117. Would you have the cistern underground?—No, the cistern should be at the highest point as a rule, not invariably so perhaps, but as a rule it should be at the highest part of the house.

5118. I am speaking of houses where one cistern would supply several houses, would you have that cistern underground with a pump by which they might draw the water, or above ground with a tap?—I should prefer having the cistern above ground, so that they could draw the water by a tap instead of by a pump, but it is not very material.

5119. Would not a tap be more liable to abuse, would not less water run to waste if a pump were used?—No, because where there is very little pressure it is easy so to arrange that the drawing cock shall close itself the moment the hand is taken off. There is no difficulty about that, but there is great difficulty where there is a heavy pressure and considerable power, because then the shock of the closing of this valve is apt to occasion a sort of aneurism in the pipe. It gradually swells out with each successive blow, and at last there comes a gap in it precisely the same as in the aneurism of an artery, and a repair is wanted which is a very undesirable thing. This objection may be to a considerable

extent removed by the use of the instrument called "the screw down cock."

5120. From your experience could you say which water keeps best in large reservoirs, soft or moderately hard water?—It depends entirely upon the quality of the salts which the water contains. Some hard waters produce vegetation with very great rapidity, and soft waters always produce vegetation with great rapidity. On the other hand there are hard waters which produce scarcely any vegetation. The waters from the oolites, such as those which are used at Cheltenham for instance, and are admitted there into a large brick reservoir, stand a year exposed to the atmosphere, and scarcely any vegetation forms at all. Chalk waters are very liable to form vegetation when exposed to the atmosphere. You see confervæ in them, a long stringy matter which they call the London silkweed will grow up in a few days. Water from the new red sandstone rock is still worse, in a very large reservoir it will become quite foul in about eight or 10 days. Waters containing carbonates produce plants freely, as a rule. Where there is an excess of carbonic acid the plants feed upon it, and if there happen to be present a few nitrates as well, vegetation then proceeds with uncommon rapidity.

The witness withdrew.

CHARLES GREAVES, Esq., examined.

5121. (*Col. Harness.*) You are the engineer to the East London Waterworks?—Yes.

5122. Are you engaged in any other official capacity?—I am not acting in any other capacity.

5123. Will you describe to the Commission the source of supply of your water company and how it is distributed?—The water upon which the East London Company are dependent for their supply is the river Lea, the sources of which are in the northern parts of Hertfordshire, and to some extent in Bedfordshire, and also in Essex. The lower part of the river is supplemented by springs of the watershed, partly in the county of Middlesex; the tributary rivers which are worth naming are generally considered six in number: the union of them takes place below Hertford and Ware, and from that point downwards the increase of the river is not very large. The East London Company take their supply from the whole body of the river in its lower part, but considerably above the reach of the tide, or any influences belonging to the tide.

5124. At what point do you take it?—The locality we have named is Higham Hill in the parish of Walthamstow; that is the best definition that we can give to it.

5125. How far does the tide flow up the Lea; not far above the docks, does it?—Yes, considerably above the docks.

5126. Is there not a dam or lock across there?—There are gates across one branch of the river, but at a certain point the river is divided into four or five millstreams, and the water goes up those millstreams, and so finds its way into the Hackney marshes, where the limit of the tide may be said to be. In fact, at the Ford, by Temple Mills, the city bound stones have stood for many years, and that was always considered to be the limit of the city jurisdiction on the Lea, as one of the tributaries of the Thames.

5127. How far from the mouth of the river does the tide flow?—I think it measures four miles, taking twists.

5128. How far above that is it that you take your supply?—About four miles above that.

5129. Have you only one point at which you take it?—We divert the course of the river into our works and take it as we require, and we let the surplus go by. These works, the most extensive in London, consist of a number of millstreams and reservoirs, which the company have had to put themselves in possession of. We are, as it were, becoming the owners of the whole river, and therefore we cannot be said to take it out of the river, as might be the case with some other works; we do not simply go to the edge of the river and take the quantity we want, but we appropriate the whole river.

5130. What quantity are you now taking out of the stream?—We are now delivering something under 20,000,000 gallons a day.

5131. What proportion is that of the stream which passes by you?—That will vary entirely with the season; during the year 1864 we took the whole of the volume; there was nothing went by, and we have had to plead poverty before the committee of the House of Commons, while arguing the necessity for going to the Thames to help ourselves with a supply from that river.

5132. From the river Lea you could not increase your supply, could you?—We shall be able to do so; I have a bill before Parliament now for increasing my reservoir room in the valley of the Lea, by which means I shall be able, having stored the water during the rainy seasons, to give a larger supply during seasons of drought, and I may be able to supplement my daily supply by the quantity which would be found by multiplying any given quantity, which you may choose to name, by any given number of days over which you may suppose the supply to be spread.

5133. Will you describe the scheme by which you propose to obtain a sufficient supply by storage in the valley of the Lea?—It is merely by the formation of reservoirs, partly by excavation and partly by embanking, in which the water will be impounded during the time when there is plenty.

5134. At what part of the valley is that?—Those reservoirs which will be in the parish of Walthamstow, in the lower part of the valley of the Lea, will not be dependent upon any one tributary alone, but upon the whole body of the river after receiving all its tributaries and its accretions.

5135. What is the size of the reservoirs which you propose to make?—I have at present 110 acres and I am going to have another 100 acres.

5136. With what depth of water?—The depth will be generally about 11 feet, but some parts will be deeper.

5137. What quantity of water will that store for you?—I expect to be able to store, when I have the whole storage in operation, about 500,000,000 gallons.

5138. For how many days supply?—5,000,000 gallons a day over 100 days we may say.

5139. (*Mr. Harrison.*) In dry seasons that would raise the quantity to 26,000,000?—Yes, according to any number of days that it is thought advisable to multiply by; it would give 5,000,000 gallons a day over 100 days.

5140. You are seeking power, are you not, under the bill which has now passed through the House of Commons to take 10,000,000 gallons from the Thames above Teddington?—Yes; that bill has passed the committee of the House of Commons and we have no reason to doubt that it will be granted by the House of Lords.

5141. They have put some restrictive clause into your bill, have they not, with reference to any future legislation?—They have not yet put it in, but the chairman said that the preamble of the bill was granted with the proviso that the committee should be at liberty to put into the bill anything which Parliament might determine this session.

5142. From your experience, what is a fair supply per head to calculate upon including every purpose?—The question has some range in it, because one district will have in it a much larger proportion of manufacturing works than another.

5143. Taking the population of London as a whole, what should you say?—I cannot see but what the

C. Greaves, Esq.

6 June 1867.

whole population of London ought to be very well satisfied with 24 gallons per head.

5144. You have made in your own district some special records upon the quantity actually consumed, have you not?—Yes, I have taken some pains to ascertain in special detail what was the proportion used in one place and another.

5145. Can you give the Commission the result of that?—I can give 15 cases of streets. One street averaged 306 gallons per house per day; the number of inhabitants I do not know; I have taken it per house. Those quantities were determined by the insertion of meters on the supply pipe of the street without any particular information or instruction to the people that they were being metered, but merely as a source of information for ourselves.

5146. What would you take as the average population of each house?—7½ I should think. No. 1 street comes out at 306 gallons per day; No. 2 at 329 gallons; No. 3 at 283 gallons; No. 4 at 132 gallons; No. 5 at 90 gallons; No. 6 at 96 gallons; No. 7 at 148 gallons; No. 8 at 45 gallons; No. 9 at 87 gallons; No. 10 at 194 gallons; No. 11 at 78 gallons; No. 12 at 358 gallons; No. 13 at 146 gallons; No. 14 at 73 gallons; and No. 15 at 37 gallons.

The witness delivered in the following table:

——	No. of Houses.	Duration of Experiment. No. of Years.	Gallons per House per Day.	——
No. 1	25	5½	306	45*l.* and taxes.
„ 2	37	5½	329	45*l.* do.
„ 3	35	5½	283	8*s.* 6*d.* a week.
„ 4	42	2	132	18*l.* and taxes.
„ 5	87	4½	90	22*l.* do.
„ 6	88	5½	96	10*s.* a week.
„ 7	92	5	148	23*l.*
„ 8	33	3	45	10*s.* a week.
„ 9	69	5	87	20*l.* and taxes.
„ 10	52	5½	194	35*l.* do.
„ 11	22	4	78	24*l.* do.
„ 12	47	5½	358	17*l.* do.
„ 13	41	5½	146	24*l.* do.
„ 14	18	5½	73	24*l.* do.
„ 15	28	5½	37	20*l.* do.

Average of the supplies per house per day 160 gallons.
Mean supply do. do. 168 „

5147. (*Chairman.*) I presume the houses are of different classes?—They are considerably different.

5148. And the average of 7½ would not apply all through?—I suppose it would not, but I should be loath to be precise; we find a great many people in the small houses. All but one of them are on the constant supply.

5149. (*Mr. Prestwich.*) How do you account for those differences?—Some of the houses are of a better class and have gardens. People are wilful and do not like being restricted, and they rather dare us to reduce the quantity, and they use the water in an unfair way. Some of those who have the least supplies are people who seem to be more amenable to reason in the discussion of the matter.

5150. (*Mr. Harrison.*) Have you reduced the calculation in any way to the rental of the houses?—There is an approximate valuation of each house in the table; some are in pounds per annum besides taxes, and others are in shillings per week.

5151. Are they generally houses of 20*l.* a year and upwards?—Yes, generally.

5152. Was that the daily supply?—That was the daily supply; it was calculated for seven days a week, because they were on the constant supply and consequently they had it on every day.

5153. (*Mr. Prestwich.*) There are two or three streets which show very largely in excess of the others, is there any particular cause for that difference?—No there is no abstract cause.

5154. Was any extra care taken during that time to see that there was no waste, or was it performed under the usual conditions?—You will see that it extends over a considerable period, a good many of them are for 5½ years, and during that time they were visited and examined and hunted up as to the waste, but in many cases we could not overcome their determination to use large quantities.

5155. (*Mr. Harrison.*) What head of water have you for your constant supply generally in the low districts?—The East London district is on a low level and rather uniform. I suppose the pressure may be considered to average 40 feet in general. It will run down to 25 at times, and at times it will rise to 50.

5156. In those cases in which you have had this constant supply so long in operation did you object to it?—Not at all. I myself am rather an advocate for a constant supply on the whole. Of course claiming to have the privilege of putting a reduced orifice somewhere on the pipe so as to prevent inordinate waste, I find no difficulty in giving a constant supply in my district. I have now 25,000 houses out of 92,000 who are continuously from years end to years end on the constant supply system.

5157. (*C. Harness.*) Will you explain what you mean by a reduced orifice?—Somewhere in the pipe between the pipe which belongs to the company and the cistern which belongs to the consumer, a disc with a small hole in it is inserted so as to prevent the water being drawn beyond a certain speed. That limits the draught of the system, and it saves us from inordinate loss which we know we should suffer, because notwithstanding that we have 25,000 tenants supplied in this way we cannot leave them unguarded, we are obliged to visit and inspect continuously over and over again.

5158. That limits the size of the supply pipe to the cistern?—Yes.

5159. (*Mr. Prestwich.*) What class of houses do you supply in this way?—We supply without distinction now.

5160. But does that include any of the poorer class of houses?—Yes, in fact ⅞ths, perhaps, $\frac{9}{10}$ths of all the houses that we are laying on now we are laying on upon the constant system.

5161. (*Col. Harness.*) And all upon that principle?—Yes, all upon that principle.

5162. (*Mr. Harrison.*) With regard to the poor people your experience would be, I presume, that it is of vital consequence to them to have a good supply of water?—Yes, it is. I advocate giving a complete and good supply to the poor on every possible ground, moral, social, and physical, with reference to the ordinary comforts of life. I think the absence of a proper supply of water to the poor is one of the grievances of the day.

5163. (*Col. Harness.*) When you do adopt that system and apply a contracted disc for the water to pass through you have of course to assume that you will allow them to have a certain supply in 24 hours?—Yes, certainly.

5164. What do you assume in that case?—I assume, say 180 gallons in 24 hours per house, that is the maximum, that is to say if they have no ball-cock nor any check upon it and they were to rob me to the utmost they could only take to the extent of 180 gallons a day. A pint a minute is 180 gallons a day.

5165. You calculate the size of your supply pipe by assuming that 180 gallons shall pass through it in 24 hours?—Yes, experience shows us that at the pressure of the district it will amount to 180 gallons, which is a very convenient datum to assume; the orifice is a small one, it is easily constructed, and it would have to vary with the pressure.

5166. (*Mr. Prestwich.*) Have you found that the constant supply to the poorer class of houses has led to any greater waste of water than under the intermittent supply?—I do not think it has.

5167. Has it not been apt to interfere with the works or with the taps and pipes, and so on?—There is a subordinate advantage which arises from

the use of the contracting ferule which delivers the water, that it certainly diminishes to a useful extent the pressure upon the ball-cocks. The pressure upon the tap and ball-cock where the pressure is very high is very apt to cut it out, and to make it wear and get out of order, and that is to some extent avoided by the contracted orifice through which the whole of the supply comes. There is no doubt that in towns where the constant supply is in practice, and where the pressure is very high the wear and tear of cocks is very great and the expense to the consumer is considerable in maintaining them in repair.

5168. (*Mr. Harrison.*) With regard to the quality of your water the analysis which has been made of it during the last month in the Registrar General report states this :—"The water supplied by the East London "Company from their reservoirs at Old Ford has "been specially examined for present sewage contami- "nation (that is sewage existing as such at the time "the analysis was made) but no such contamination "was detected"?—Yes, that is Dr. Frankland's analysis of the water for the month of May.

5169. Have you seen the report which has just been issued out from the River Pollution Commissioners?—Yes, I have.

5170. They recommend that the same course should be followed in the Lea as had been adopted by Act of Parliament with regard to the Thames, but giving power to a new body to prevent the pollution of the Lea for the future. If that were carried out do you think it would add to the good quality of your water?—I have not the least doubt that it would. I think that the report which the River Pollution Commissioners have issued is very well drawn, and that the conclusion that they have come to is the right conclusion. I do not see anything in it to quarrel with at all.

5171. Looking to the report based on Dr. Frankland's analysis—speaking of the water of Loch Katrine supplied to Glasgow—that water is stated to contain in every 100,000 tons three tons of foreign matter, and then comparing that with the East London water the East London water is stated to contain 27 tons of foreign matter per 100,000 tons?—Yes.

5172. Possibly a good deal of that foreign matter which is now found in your East London water would be done away with by the operation of what the River Pollution Commissioners suggest?—No, I think not much, because all the effect of any works such as the Pollution Commissioners propose would be the removal of organic matter, which is a very small portion of the whole of the contents. The difference between the total contents of the Loch Katrine water and the river Lea water arises out of the fact of the river Lea being moderately hard water, it is that which contributes to the hardness which is the great component of those tons of foreign matter.

5173. As regards that you think it would make no alteration in it?—Not much.

5174. Is Dr. Frankland appointed officially by any Government office to make those reports?—I really am not able to answer that question, but as the Registrar General and Dr. Frankland seem quite to understand one another in the matter I presume Dr. Frankland is paid by the Home Office in some way. He has a remuneration for his analyses I believe; but I do know this that Dr. Dundas Thompson who carried on those analyses for many years received the very smallest possible pittance for the trouble which he took in doing it.

5175. Do you consider it desirable that some official person should make such reports regularly monthly of all the waters?—I think it is a very satisfactory thing that it is done through some Government department so as to be above any kind of suspicion.

5176. As being to the water companies satisfactory as well as to that of the public?—Yes; both to the companies and to the public certainly.

5177. You have of course had your attention directed a great deal to the river Lea, and although you have gone this session to Parliament to obtain a large quantity from the Thames above Teddington, yet do you consider the resources of the Lea to be now exhausted by your two companies, the New River and the East London taking water from it, I mean independent of the question of the cost of getting it, but taking it as a purely physical question?—I am of opinion that as the larger portion of London is dependent upon the Lea it ought not to continue any longer dependent upon the Lea alone for its supply of water as to quantity. The caution that we had from the drought of 1864 was convincing. There is no room to doubt the question any longer.

5178. In the case of the New River their engineer has stated that he believes it is quite capable of yielding 10,000,000 gallons to each of the companies in addition to the present quantity by proper storage reservoirs, do you concur in that view?—I am not inclined to store so largely or to depend upon storage to that extent, because I know that there are winters when it is quite likely those reservoirs might not be filled. The winter of 1858 went off without a single flood; we have charge of the flood-gates ourselves on the river at Lea Bridge which govern the whole flow, and in the winter of 1858 we did not draw a single gate; therefore where would the reservoirs be filled from in such a season?

5179. I gather that your view would be that you would prefer going to the Thames proper for any additional supply, leaving the Lea to be applied to in case of necessity some 100 years hence?—I am going to make a 100 acre reservoir now upon the Lea in addition to what I have got. I shall combine my Thames works and my Lea works together, and if I cannot fill my Lea works with the Lea water I shall fill them with the Thames water. I should not rely on the Lea alone or on the Thames alone, but I should allow my reservoir in the Lea to be filled from the Thames when necessary. I consider the Lea alone not to be depended on even for the East London, and less so supposing the New River Company do an equal amount of work.

5180. Have you a thorough knowledge of the whole of the Thames basin?—Pretty well, but not so intimately as I have of the Lea.

5181. You heard the evidence which was given just now by Mr. Hawksley?—Yes.

5182. Do you agree generally in the views which he expressed?—No, I cannot say that I do. I do not think these rivers are going to last so long as Mr. Hawksley does. I think it is necessary to be cautious in time. I would not like speculating upon any one of those rivers round London lasting for the next half century; not only the Lea or the Thames, but other rivers; I mean lasting as a source of water supply independent of any foreign aid.

5183. You calculate that you may have to go beyond the Thames basin for the supply of London?—I think it is quite a fair thing in prospect to talk about. I do not think there is anything foolish in the view that it may be necessary to go beyond the Thames basin; that is to say, you will either have to do that or to store very largely, more largely than anyone has entered into the practical estimation of.

5184. Should you agree with Mr. Hawksley in his opinion that you might take 150,000,000 gallons daily, without the necessity of storage?—I should hardly like to commit myself to that opinion, because we do not know yet the complete effect of the removal of sewage from the Thames by the main drainage works; we do not know whether future droughts may not be more trying and disastrous to the river than the droughts which we have had experience of. The drought of 1864 surpassed anything that anyone knew of at all; we have no records anywhere of the loss of water going on to such an extent as took place in that season. It is known by gauging and special observations that we lost quite 13 inches of water by evaporation from enclosed reservoirs during the summer months of that year.

C. Greaves, Esq.

6 June 1867.

5185. Do you incline to the opinion that it is necessary at this time of day to look to other sources of supply than the Thames?—I think it is taking the subject quite early enough to talk about it, but I do not think the time is come for going beyond the Thames.

5186. (*Col. Harness.*) Do you mean that 13 inches were lost in the depth of the reservoirs?—Yes, I mean 13 inches in depth of water.

3187. (*Mr. Harrison.*) You do not put any number of years to come as the probable time?—There are so many things to be considered that I hardly think it is worth while entering into any definite estimate of years. We are told by Professor Glaisher that the temperature of the country is increasing, that we have an average rise of one degree. These things affect the question of evaporation immensely. It is a scientific point which is not at all sufficiently understood, that four-fifths of all the rain which falls from heaven is re-evaporated from the earth. We have rain-gauges all over the kingdom by means of which we should have no trouble at all in measuring the quantity of rain that falls, but it seems very few people can be found to take any trouble to measure the quantity of water that is re-evaporated. If we have an average rainfall of 25 inches, and during any considerable period of successive years, 20 inches of water is re-vaporated in the same time, you have only five inches of water to deal with, and that five inches is the result of the temperature and climate of the country, but if that temperature increased the five inches would be diminished, and we find that this really does take place in the hot years, particularly when two or three hot years came in succession.

5188. (*Mr. Prestwich.*) You have probably observed that the Lea water would hardly be affected by the introduction of the present system of drainage of agricultural lands, but do you think that it is likely to affect the flow of our larger rivers?—There seems to be a general idea that the discharge of the river waters is quicker than it used to be.

5189. Especially when it passes through clay lands?—Yes.

5190. The Lea, coming from a chalk district, would hardly feel the effect of that?—I do not know that the conclusion is altogether certain, that such is the effect I agree with Mr. Bailey Denton, to a certain extent, that under-drainage carries a great deal of water down into the soil, in fact the whole philosophy of draining as a method of raising the temperature consists in that point that a great deal of water is carried from the surface down into the under drains and pervades the soil before it reaches the under drains and is not shed off or evaporated from the actual surface as is the case in an ill-drained country. The enlargement of the main carriers certainly quickens the delivery of the water off the district, but the modern process of under draining may not do that.

5191. But it would affect in some way or other the flow of water in the river either to spread it over a greater extent of time or to make the flow more rapid?—There seems to be a general opinion that the discharge of rivers is affected by drainage and quickened.

5192. And that is a process which is now going on to an increasing extent?—Yes.

5193. But in a river like that from which you draw your supply passing through a chalk area where springs flow with great regularity, it can hardly be affected by such a cause as that?—No, so far as it is dependent on those springs.

5194. With regard to the future supply to London, do you think that at any time the springs in the chalk below London might be rendered available for the supplies of the districts east of London?—I do not think that there are any springs in the chalk to any great extent on the east of London.

5195. You are acquainted with the springs at Grays, I presume?—Yes.

5196. We have been given to understand that they could deliver and have been proved to deliver 10,000,000 gallons of water a day?—I understand that that delivery is claimed by parties interested, but the water in the chalk there, if indeed it can be called a spring, is at a very low level, at a level no higher than the Thames, and therefore the sources of that water to my mind are rather uncertain.

5197. That quantity has been determined by pumping, has it not?—Yes, there have been a series of excavations in the chalk there, but no passage of water takes place at all without pumping.

5198. But do you not consider that the circumstance of their having pumped three days in succession and obtained that quantity shows that the springs are of considerable power?—I have no doubt that there are springs, but the extent of which the water may be drawn upon is a difficult point to determine. I am not inclined to think that they can be depended upon to the extent which is claimed for them.

5199. At present the limit of their supply I believe is at Brentwood and Romford?—The water supplied from there is but small; I have been acquainted with the springs for years; they were offered to our company before the present company entered into the speculation, and I examined them repeatedly before anything was done in the way of forming them into a water company for supply, and if I had seen a natural continuous flow, or any indication that the water was discharging itself at low-water mark into the river, or in any other way, I should have looked upon them with a different eye.

5200. I presume that the overflow from those springs would find its way to the river nearly at low water?—Yes; but I walked the whole of the low-water line of the river but I never could see any trace of any water coming out. I went especially to find out that particular point, because if I had found water issuing even at low-water mark I should have concluded that there was a certainty of the springs being powerful.

5201. Coming through the gravel it would be dispersed over a very large surface and would not show much at any one point?—Quite so; but I think where such springs are known to exist they do flow, and you see an indication of them somewhere above low-water mark in the mud, or the silt deposit.

5202. (*Mr. Harrison.*) Is there any other point which you could suggest of interest to this Commission, knowing as you do the subject of their inquiry?—I hardly know whether there is or not. I have been before so many boards of inquiry lately that I am exhausted upon almost every subject. I have had to tabulate and to summarize almost every matter connected with the affairs of the river Lea and my company in every shape and way. I have some papers here which I can hand in with regard to the constant supply of poor courts. We have found lately the advantage of putting up an aparatus for supplying courts with a cistern; not an apparatus which is charged direct from the main but with an arrangement of drawing-taps, made so that the charging and the drawing cannot take place at the same moment. The cock is what we call technically a three-way cock. When you draw from the vessel you shut the connexion with the main, and when you release the handle by which you draw, it charges itself again from the main immediately of its own accord.

5203. (*Chairman.*) Without moving it again you can only draw a certain quantity?—That is so.

5204. How much do you allow them to draw with one movement?—About a gallon or a gallon and a quarter. We find that mode of construction acts very well, two or three charges will fill a pail. The machine is made of cast-iron, and there is nothing about it that can be stolen; it is fastened to the wall, and the people enjoy the advantage of the water being fresh. I have in my hand a list of places where we have put them up, with the number of houses dependent upon each apparatus.

The witness delivered in the following table:

WASTE PREVENTERS.

Where fixed and the number of houses on each, 21st May 1867.

Situation.	No. of Houses.
Angel Alley, High Street, Whitechapel	6
Ann's Place, Boundary Street	8
Bud's Cottages, Portman's Place, Mile End	5
Charlotte Place, Turoit Street, Charlders	5
Crown Court, Wentworth Street	14
Caroline Place, Whitechapel	12
Diamond Court, Great Pearl Street	7
Dalston Square, Nelson Street	6
Dinah's Buildings, Cox's Square	12
Duncan Court, Boundary Street	12
E. L. W. W. Co. Cottages, Horsepond, Stratford	4
George Court, Harriss Court	14
Gibraltar Gardens, No. 1 } Do. No. 2 }	32
Hewett's Court, Jubilee Street	7
Hobson's Place, Pelham Street	14
Hobson's Court, Mile End New Town	15
Hank's Court, Poplar	10
Inkhorn Court	9
John's Place, Hunt Street	14
Jones Buildings, Gower's Walk	27
Neatsby's Court, Fashion Street	3
New Court, Great Pearl Street	10
New Court, George Yard, Whitechapel	6
New Square, Quaker Street, Spitalfields	9
Montague Court, City (fixed by the City Commissioners)	16
Old Montague Court, Spitalfields	6
Pennock's Place, Plaistow	9
Pooles Square, Quaker Street	6
Pratt's Alley, Little North Street	8
Providence Court, Glasshouse Street	9
Queen's Court, Wells Street	7
Ruins, Harris Court, No. 1	2
Do. No. 2	7
Reform Square	5
Silver Lion Court, Pennyfields Poplar	14
Single Place, Bridge Street, Mile End	14
Silkmill Row, Hackney Wick	6
Thorold Square	16
Tewksbury Buildings	14
Trumpet Court, Black Lion Yard, Whitechapel	14
Vine Yard Place, Harris's Court	10
Wells Place, Gower's Walk, Whitechapel	30
Weatherhead Gardens, No. 1 } Do. No. 2 }	24
White Bear Court	23
Peacock's Place, Bethnal Green (Chandlers)	8
Channelsea Court, Stratford do.	13
Godfrey's Place, High Hill Ferry (Pilbrows)	12
Brick Cottages, do. do.	8
Saxony Cottages, Mare Street (Chandlers)	7
St. Thomas's Place, Lime Grove, do.	8
Garden Place, Chicksand Street (Pilbrows)	15
Osborn Court, Brick Lane, do.	4
	576

(*Witness.*) I have also a table showing the per-centage of the houses on constant supply which I find has gone on increasing from four up to 28 per cent. These are probably all on the principle of a contracted orifice.

The witness delivered in the following table:

PER-CENTAGE OF CONSTANTS.

1854	66,191	2,898	4·37
1855	68,053	4,134	6·07
1856	69,876	5,299	7·58
1857	70,938	6,000	8·45
1858	72,442	7,056	9·74
1859	74,201	9,000	12·12
1860	76,310	11,000	14·41
1861	77,944	12,712	16·30
1862	79,748	15,140	18·98
1863	82,556	18,000	21·80
1864	84,564	20,000	23·65
1865	87,278	22,497	25·77
1166	88,945	25,305	28·45

5205. (*Mr. Prestwich*) Then you avoid any difficulty from excessive waste?—Yes; which is always the argument against the constant supply system. I can also furnish the Commission with some other figures. In addition to the experiment carried on on a large scale, covering the whole supply of the district by large meters. I can give an instance of a district including 9,031 houses. It did not affect the rents or the pecuniary arrangements between the company and the people, and I find that out of the 9,031 houses those on the constant supply amount to 73 per cent., the remainder are on the intermittent supply. The water taken by the houses on the constant supply is 118 gallons per house per day for seven days.

2506. (*Mr. Harrison.*) Taking them at five to a house, which would be a very small number that would give 24 gallons per head?—They are not stinted and there is no complaint. The district is wholesale under the constant supply, and that is the result as a matter of experiment.

5207. Would that include water for sewage and everything?—No, not at all; first of all the gross supply is taken out, as given to the district—from that is deducted all that is supplied by meters to manufactories, the road watering as supplied by meter, and every kind of trade and manufacturing, and the remainder is the domestic supply proper, which when divided by the number of domestic tenants gives 118 gallons per house per day for seven days a week.

5208. Captain Tyler has taken for your district 7½ gallons per head, has he not?—I gave him the figure correctly, and as computed from the census it comes out 7·3 gallons. I take the whole of the district from the census of 1861, the number of inhabited houses and the population; there can be no better way of getting at it.

5209. In round numbers you may take it to be about 15 gallons per head?—Yes, for domestic use exclusively.

5210. (*Mr. Prestwich.*) Do you use the same water for domestic purposes and for watering the streets?—The company are prohibited from trading in any other water; they are bound to filter all their water; they have no exceptional clause entitling them to use any second-rate water; and therefore the same quality of water is used for whatever purposes it may be required.

5211. Do you think it would be desirable to separate the water required for domestic purposes from that required for flushing the sewers?—The cost of filtering is not so very great, and it is better to filter it all; it might be an advantage to escape the cost of filtering on a certain quantity, but it would lead to uncertainty; because then the people might be buying second-rate water from the company under the guise of trade and using it for culinary and domestic purposes, which would be contrary to the intention of the Legislature.

The witness withdrew.

Adjourned to Thursday the 20th of June at 11 o'clock.

Thursday, 20th June 1867.

PRESENT:

SIR JOHN THWAITES IN THE CHAIR.

Alderman Sir BENJAMIN PHILLIPS.
Colonel HARNESS.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

J. Firth, Esq.
20 June 1867.

JOSIAH FIRTH, Esq., examined.

5212. (*Chairman.*) You are a member of the firm of Firth and Company, at Heckmondwyke, Yorkshire?—Yes, of the firm of Edwin Firth and Sons.

5213. You are a cloth manufacturer, are you not?—I am a manufacturer of carpets and blankets, and of cloths also.

5214. Have you been long a manufacturer of woollen goods?—I have been connected with it about 15 years.

5215. And do you take an active part in the manufacture or in the sale?—Both in the sale and in the manufacture.

5216. Do you manufacture flannel goods?—Yes, blankets and woollen cloths for army purposes chiefly.

5217. Is that a cloth requiring a great deal of scouring?—Yes.

5218. You have to wash out the soap?—Yes.

5219. (*Sir B. Phillips.*) Do you buy the yarn or spin it?—We spin the yarn and manufacture it from the wool itself.

5220. (*Chairman.*) You use a large quantity of soap, do you not, in order to get out the grease?—Yes.

5221. And necessarily a large quantity of water?—Yes.

5222. What class of water are you supplied with now?—The water that we have chiefly is from a colliery that we used to work, and that water is rather hard.

5223. Have you constituted that colliery a well?—Yes, we have constituted it a well, and we pump the water from the old works. The water is rather hard for dyeing purposes, and also for scouring purposes; it is not so good as soft water for such purposes as those.

5224. Can you tell us the degree of hardness of that water?—No, I cannot tell you that. We have also a supply of water from the town waterworks which is soft water, and very good water.

5225. And do you use that in preference to the water which you yourself possess?—Yes, for certain colours we use it. We are almost obliged to use it for the dyeing of certain colours, and we should use it for everything if we could get the requisite quantity at a reasonable price, except for black, blue, and magenta, for which colours our own water is the best.

5226. Is there great economy in the use of soft water as compared with hard?—For certain purposes of our manufacture it would be so.

5227. For what purposes?—For scouring and dyeing certain colours; for all colours I may say it is an advantage.

5228. What colours are developed better by soft water?—More particularly the lighter colours, scarlets and crimsons. It is almost indispensable for dyeing scarlet, and also for the washing out of scarlet it is very necessary to have soft water, or at all events water that is not impregnated with chemical properties which would injuriously affect the colours in any way.

5229. Do you find that you are able to use the water which you pump from the old coal shaft for dyeing purposes?—Not to the same advantage as the town's water, which is soft.

5230. You find it not so good for the development of colours or for scouring purposes?—Certainly not.

5231. Do you know the relative value of the water in an economical point of view?—No, that is a thing which we have not tested; except for scouring yarns, where we find by using the towns' water we effect a saving of 25 per cent. of the quantity of soap used for this purpose.

5232. Have you observed at all the consumption of soap in using the water which you pump from the coal shaft as compared with the amount of soap used with water which is of a soft character?—I may say that the supply from the waterworks is not sufficient for our use in our works, we are obliged to confine ourselves to our own water, except for certain colours.

5233. I understand you to state that for the purposes of developing certain colours, and especially light colours, scarlet and others, and also for scouring purposes, soft water is very much preferred by you?—Yes.

5234. I ask you if you can give any reason why you prefer it, or if you can give any reason as to the comparative consumption of soap by the one system or the other?—We have not tested the relative cheapness of the waters as regards their scouring properties, except, as before said, in the case of yarn scouring.

5235. Are not manufacturers generally, especially Yorkshire manufacturers, quite alive to that consideration?—The fact is that we have not the necessary quantity of soft water to make use of. We are quite aware of the fact that it has a decided advantage over hard water, but not having a soft water we are obliged to content ourselves with the hard water in our well.

5236. Is that from the insufficiency of supply, or is it because of the cost?—From the insufficiency of supply.

5237. What quantity of soft water are you taking for your manufacturing purposes from the water company?—We should use more if we could get it, at present we average about 2,700,000 gallons yearly, and the price is 6*d.* per 1,000 gallons.

5238. What the Commission desire to know is, in the first place, the class of water that you are using, and if soft, why you are using soft water, and what are the economic advantages in the use of soft as compared with hard water for manufacturing purposes, and especially the class of manufactures such as is carried on by your firm?—I can merely give our general experience that soft water has a considerable advantage over hard water. We have not had a sufficient supply of soft water, and cannot get it, no matter what the price is at present. If we had a supply of soft water offered to us for certain purposes we should use it whatever the cost was. For other purposes we should then have to estimate the difference in value between the hard and the soft waters, independent upon the price of the soft water as compared with the hard. If the price was equal for all purposes we should undoubtedly give the preference to soft water.

5239. (*Col. Harness.*) Are you now taking all the water that the company will give you, or are you only taking such a quantity as you think fit to pay for?—We cannot take the whole that we require, nor can we apply it to the purposes which we should do, because we cannot depend upon it, and it would not pay us to lay down pipes and everything of that sort unless we could depend upon a regular supply.

5240. Then the supply is uncertain?—Yes, the supply is uncertain.

5241. What do the company charge for the water?—Sixpence per 1,000 gallons.

5242. What do you think the water which you get from your own well costs you?—We think that it costs us about one half of that; it costs us quite half, because we are obliged to pump the whole of the water out on account of its being an old colliery; the water is affected by the old works, and therefore we are obliged to pump the whole of the water in order to keep it clean, to keep it clear from canker.

5243. (*Chairman.*) Are you obliged to keep the pump constantly going?—Yes, day and night.

5244. Have you any iron in that water?—Yes.

5245. That is an objection, is it not?—Yes, for everything except the dyeing of black, blue, and magenta, for which it is an advantage.

5246. (*Sir B. Phillips.*) Do you mean that it is an objection for dyeing purposes?—Yes, and for scouring purposes also, except as aforesaid.

5247. You state that you prefer soft water to hard water; do you also state that if you could get a sufficient quantity of soft water at any price you would take it in preference to the other?—For some colours we should.

5248. Do you find an advantage in the use of soft water in the brilliancy of the colour that is produced?—Yes.

5249. Have you an advantage in the return in weight?—Yes, and in the brilliancy and clearness of the colour.

5250. How is it with regard to the dark colours?—In dark colours, such as black, it is not of the same importance.

5251. Do you scour your yarn before you dye?—Yes.

5252. Do you never scour anything after it is woven or dyed in the piece?—Yes.

5253. I suppose you dye your scarlets in the piece?—Yes.

5254. Do you find that you get a brighter colour from soft water than you do from hard in scarlets?—Yes.

5255. Do you ever scour your yarns first, and then dye them, and then weave them?—We do for carpets; in that case the yarns are always scoured first.

5256. As a rule, you find that you get a better colour from soft water than you do from hard water?—Yes; that is to say, we find it so with regard to light colours.

5257. What are the advantages, irrespective of colour, in the use of soft water as compared with hard water?—We find that it scours and otherwise cleanses the yarns, or cleanses the pieces with very much less soap, and better than the hard water does, but at the same time I am not prepared to say what the difference is. We have not tested that, because there was really no necessity for it; we have no soft water to use.

5258. Supposing that soft water cost you 6*d.* per 1,000 gallons, and that hard water cost you 3*d.* per 1,000; taking into consideration the difference in the brilliancy of the colour, and the difference in the quantity of soap which you would require in the use of soft water as compared with hard water, do you think that soft water would be cheaper for your manufacturing purposes as a whole than hard water?—As a whole I think it would, because some of the things which we manufacture are blankets, which we dye in the piece. With regard to anything that is dark in colour, such as grey blankets, or black, or brown, or any dark colour of that character, I should consider that hard water would not be objectionable for either dyeing or for washing off, but of course it would be in the cleansing.

5259. (*Chairman.*) Do you ever dye blankets?—Yes, we dye a great many blankets for foreign markets; they are not of much use in the English market.

5260. Are they dyed in order to save washing?—I do not know.

5261. (*Sir B. Phillips.*) In dyeing those blankets, does the soft water improve the texture?—I should think it would.

5262. (*Mr. Harrison.*) What water do you use for household purposes?—We use the soft water.

5263. Do you use it from choice, or from expediency?—From choice, decidedly.

5264. Do you prefer drinking soft water to hard?—Yes, decidedly; we prefer for drinking purposes soft water to hard water as a matter of taste.

5265. (*Chairman.*) How many hands do you employ?—About 1,700, averaged, but sometimes I daresay we double this, in fact I may safely say we have tripled it.

5266. Do the people use the soft water in their houses?—Yes, certainly, so far as we are acquainted with their houses. We have a great number of our own houses, and we have had the towns' water put into those houses.

5267. Generally speaking, if you had a choice you would prefer, would you not, soft water for all the purposes of your manufacture?—Certainly.

5268. And you believe that economy would be consulted by the use of it in preference to hard?—Yes, even if it were at the same price.

5269. But you are not prepared to tell us to what extent would be your saving by the use of soft instead of hard water?—I am not prepared to say that.

5270. From what you have observed as a practical man, in scouring and in getting rid of grease and other matters which you have to scour out either of yarn or of manufactured goods, those things appear to be removed with greater rapidity and with the consumption of less soap by the use of soft water than by hard?—Yes, I may say that we have tested it in our case; in the scouring of yarns and saving of soap from the use of soft water over hard would be about 25 per cent.

5271. (*Sir B. Phillips.*) What amount of soap do you use annually?—I cannot say that off hand. Our production varies very much, and therefore the use of soap varies.

5272. (*Mr Harrison.*) But your consumption of soap must be exceedingly large, must it not?—Yes.

5273. (*Mr. Prestwich.*) What is the source of supply for the town water?—We can connect with the Dewsbury, Batley, and Heckmondwike Waterworks, and they get the water from Dunford Bridge near Penistone, between Penistone and Sheffield, from the river Don.

5274. Do you know the hardness of the water which is supplied by the town?—That is soft water.

5275. I presume you mean that it is more or less soft, but it would still show a certain amount of hardness whether it were 1, 2, or 3 degrees?—I should think it would be a few degrees of hardness, but I cannot say exactly what.

5276. Can you tell us the degrees of hardness of the water from the well?—No.

5277. Has the well water ever been analysed?—No, but the town's water has been analysed, I believe.

5278. Could you furnish us with that analysis?—I am not able to do so; I am informed that it is the next water to the Whitehaven for purity, which is one of the very purest waters, and that it is about 3 degrees of hardness.

5279. You state do you not, that the water in the well contains iron?—Yes, there are iron beds there in connexion with the coal.

5280. That of itself would render the water objectionable for manufacturing purposes?—Yes, to some extent it is an objection.

5281. Therefore you could not tell us, supposing the water were free from the iron, whether the presence of any other ingredient causing the water to be hard, such as carbonate of lime, would or would not be objectionable?—It certainly would.

5282. You have stated clearly that the use of hard water is objectionable on the score of economy, and that there is a saving in the consumption of soap between the use of soft as compared with hard water, and with regard to colours you state that for certain purposes you prefer to use soft water?—Yes.

5283. But that is soft water compared with the water which you use from your wells, which you say

J. Firth, Esq.
20 June 1867.

contains a certain quantity of iron, but I want to know whether apart from the presence of iron you know of any other objection to the use of water containing carbonate of lime?—I may say that we have used this water before the colliery was framed. We had the same water in its hard state unconnected with the iron, and we got it at a less depth. Our colliery is now 80 yards deep, and we then had the water at 20 yards, still it was hard water, and taking it at that point I should give the preference to soft water.

5284. Do you know through what strata it passed to the depth of 20 yards?—I do not know, but it was not iron. The water in our neighbourhood throughout has a slight proportion of iron in it.

5285. Are there any limestone beds in your neighbourhood?—No.

5286. You are probably well acquainted with the manufactures in France of a similar class to your own?—Yes.

5287. Do you know the results produced at Amiens in the dyeing of carpets, and Rheims in the dyeing of woollens?—Yes, they dye brighter colours than we do.

5288. Probably you are not aware that both the waters used at Amiens and Rheims come from a chalk country and contain a good deal of carbonate of lime?—No, I do not know the properties of the water that they use.

5289. That is why I wanted to elicit from you whether you knew positively from your own information that the objections which are raised to the use of hard water in your neighbourhood arose from the presence of carbonate of lime, which is the usual ingredient of hard water, or from some other substance, such as you have mentioned, namely, the presence of iron?—No doubt the water is very much injured by the presence of lime, and more so than it would be if the hardness had been produced merely by carbonate of lime; but at the same time, comparing soft with hard water, I should consider that even if our well water had no iron properties about it, soft water would be preferable for dyeing purposes.

5290. You stated just now that you consider that the colours produced both at Amiens and at Rheims are superior to the colours usually produced in this country?—Yes.

5291. And if I tell you that the waters used in both those towns are chalk waters, containing a good deal of carbonate of lime, and that they use no other waters, how do you reconcile that with the opinion which you before expressed that soft waters are better for dyeing purposes?—Because I say that we have no really good water for dyeing purposes in our neighbourhood excepting the town's water, and that is good water.

5292. Then all that you mean to say is that the town's water is better water than the water from your own well for dyeing purposes?—Yes.

5293. (*Chairman.*) So far as your evidence goes, I understand that it is entirely confined to the water which you have been using, either from the well or from the company who supply the town?—Yes.

5294. And that you are unable to state what are the properties of that water which you pump from the well, except that you have detected the presence of iron?—Yes, but since this question was put I have had our water analysed, and at foot give particulars of it; it was taken at an unfavourable time, the water being high in the old works.

5295. And that you believe in any case would be objectionable for dyeing and scouring purposes?—Yes, for certain colours it would.

5296. Do you know generally the watershed which supplies the water to the company?—Yes, I know the district.

5297. Is it moor or pasture land?—It is moor land.

5298. Is there any peat on it?—Yes, there is a great deal of peat there.

5299. Is the water coloured at all with the peaty matter?—No, it is very clear water.

5300. In times of flood have you observed any colour in the water?—I think that as a rule it runs in a very clear state into the reservoir which is very near the supply.

5301. Is it not of a brown peaty colour?—I think not.

5302. At least you have not observed it?—I have not observed it.

5303. (*Mr. Harrison.*) You get up near to the millstone grit where your source of supply comes from, do you not?—Yes.

5304. Is there any other point which occurs to you upon which you can give information to the Commission?—I can mention the revenue of the waterworks for 1864, and the different purposes for which it was used. For domestic purposes the revenue was 796*l.* 5*s.*, and for mill purposes 216*l.* It has very much increased since that time. In our district, particularly in Batley and Dewsbury, there is a large quantity of cloth of dark colours produced, and also blankets of dark colours, and for those purposes probably the advantage of soft water would not be so great as in our trade, because in a blanket it is not only necessary to have it clean and bright and white, which we always find soft water produces as compared with hard water, but also to have it soft.

5305. (*Chairman.*) Are you able to express an opinion as to the value of water in the manufacture of saxon wool?—We do not use saxon wool.

5306. But you are, no doubt, acquainted with the manufacture of Huddersfield and Leeds, and that district, where they manufacture fine cloth?—Yes.

5307. It would be very important for scouring purposes that they should have soft water there, would it not?—I should think so, for the trousering trade. They make there plain black cloths, and also fancy mixtures; and I should think, for fancy mixtures and trouserings which are dyed in the yarn, the soft water would be an advantage.

5308. (*Sir B. Phillips.*) Would not all light woollen fabrics be better dyed with soft water than with hard?—Yes.

5309. (*Mr. Prestwich.*) You are in the midst of a large coal district, are you not?—Yes, we are.

5310. Is the towns supply as soft as that from the Holmfirth reservoir?—Yes, it is as good as that. We find a decided advantage in dyeing with the town's water, and a decided advantage in scouring and cleansing with it.

5311. (*Chairman.*) I presume that the real cost of soft water compared with hard water is as nothing when compared with the increased value of the article in consequence of the bright clear colours which the soft water would produce?—Certainly, that is so.

5312. (*Mr. Prestwich.*) Do you know the relative quantity of water which you use for scouring purposes and for dyeing purposes?—I could not say that. We have such an abundant supply that we do not stint it at all. If we had it from the town and had to pay for it, no doubt we should regulate the quantity; but as we have the whole of the water to pump out of our works, we do not attempt to measure what quantity we are using.

5313. You state that you do use a certain quantity of water from the town; are we to understand that you use it for all your scouring purposes?—No, not for all; only for particular bright colours.

5314. I am not now speaking of dyeing, but merely of scouring?—For scouring in the same way. When we are scouring for light colours we should use soft water.

5315. You stated that your opinion was that an economy of 25 per cent. is produced by the use of soft water in the saving of soap. Can you tell us whether you are aware of any saving with regard to the use of dyes?—No, I cannot tell that, excepting in light colours; that is to say, I cannot tell the percentage, but I daresay I could ascertain it. There is one remark which I should wish to make with regard to the dyers in France. We find, as a rule, that the working dyers of England are not as good a class of men as the French working dyers; they are not so

well educated as chemists. The French dyers really are chemists, and they study the properties of the waters. They are scientific men; whereas the working dyers that we have in this country, as a rule, are ignorant men who merely work by practice, and do not analyse the thing. In fact, you are almost entirely in their hands in the dyeing process, because they will not even go to the extent of weighing the materials. They are not the class of men that they have in France; they are not educated, in fact, and they sadly want education.

5316. (*Sir B. Phillips.*) They know nothing of the chemical properties of the material?—Nothing at all.

5317. (*Mr. Prestwich.*) Can you explain how it is that two important towns in the north of France, which are becoming the great seats of woollen dyeing, would have become so unless the waters had been suitable for the purpose, the waters in both those cases being hard chalk waters?—I cannot explain it.

5318. (*Chairman.*) But there are other elements to be taken into account besides the question of dyeing, namely, the labour, the water, the materials, and the market also?—Yes. For some colours, no doubt, iron water is cheaper to dye with than others.

5319. (*Mr. Prestwich.*) It would appear from what you state, that the waters in your district contain little or no lime, and that the hardness arises from other sources?—Yes. I may remark that I have just come from Paris now, and I find that there is very great attention paid to the education of the working men by the Government; they are educated in all the various branches of manufacture—they are schooled for this sort of thing, so that, as a rule, the men in that branch are superior. Also, in England we have in the dyeing trades parties whose business is dyeing, and the masters at the head of those establishments are, no doubt, practical dyers themselves. Whereas, in our business, we send out more to dye than we dye ourselves. We only dye certain portions of our manufactures, and from that cause there is not that necessity for ourselves to become practical dyers. In fact, we have other portions of our business which are of more importance, and to which we give our attention.

The following is an analysis made of our water by by Mr. J. Chapman Wilson, F.C.S. of Leeds, viz.:—

"In appearance the water is at first slightly turbid, but "after standing a short time exposed to the air it deposits "an ochreous-looking sediment and becomes quite bright "and clear. When boiled it deposits a copious white sedi- "ment and incrustation. An imperial gallon contains "50·03 grains of solid matter, 0·14 grains of which is "organic and soluble matter. There are present the "following salts:—

"Carbonate of lime, "Sulphate of lime, } Chiefly.
"Carbonate of magnesia,
"Cloride of sodium,
"Carbonate of iron,
"Silicia.

"The total hardness of the water is 16°, the temporary "hardness or the hardness which may be removed by "bolling is 6°, and the permanent hardness which remains "after boiling is 9°. Carbonate of protoxide of iron is held "in solution in considerable quantity, indeed sufficient to "render the water objectionable for many manufacturing "purposes, such as dyeing, &c., and its hardness lessens "its value for washing and scouring. However, by con- "tinued exposure in an open reservoir the carbonate of "protoxide of iron would be thrown down as a sediment of "yellow peroxide, and the water thus be freed from the "soluble iron salt which is prejudicial."

Our own water dyes the following colours cheapest and best, viz.: black, blue, and magenta, but in all cases for washing off goods after being dyed, the towns' water is the best. And also in scouring or cleansing yarns or pieces the towns' water is the best, and effects a saving of 25 per cent. of soap used in scouring yarns; all other colours not specified are dyed cheaper and brighter with towns' water.

The witness withdrew.

SAMUEL JUBB, Esq., examined.

5320. (*Chairman.*) What business do you carry on?—I am a woollen manufacturer at Batley, near Leeds.

5321. What class of manufacture do you carry on?—Heavy woollens for winter wear, heavy coatings such as pilot cloth, Whitney's kerseys, Petershams, and those kind of cloth which contain some shoddy and a part mungo.

5322. (*Sir B. Phillips.*) Do you make those cloths for the London markets?—Yes.

5323. (*Chairman.*) Do you use the machine called a "devil" there for tearing up the old material?—Yes.

5324. Will you state to the Commission whether you manufacture from the wool, or whether you buy your yarns?—We purchase the wool and manufacture the goods out of the wool throughout, from the first process to the last; every process is done on our premises.

5325. What class of water are you using in the manufacture?—For our dyeing we are using the surface water which we collect in a dam, but for milling and scouring we are using the towns water almost entirely, I may say entirely.

5326. Why is that?—One reason is, that we have not got a supply of water adequate to our wants, and another is that the dam water would not serve both the milling and scouring process and the dyeing process, and we find that the towns water is much better for the milling and scouring process, and we can get a supply at present, and therefore we use soft water entirely for those purposes.

5327. What is the quality of the soft water?—It is similar water to that described by Mr. Firth, it is the same supply of water.

5328. Is your manufactory near to Mr. Firth's?—Within about a mile and a half.

5329. Then you take your water from the same company?—Yes, from the same company; it is not a private company, it is the waterworks established by the three townships of Dewsbury, Batley, and Heckmondwike.

5330. Are those waterworks under the municipal authorities?—Yes.

5331. But you yourselves have some catch basin, I think you said?—Yes.

5332. And you use that water for all ordinary purposes?—We use it for the dyeing process, but the towns water we devote entirely to milling and scouring.

5333. What is the nature of the water that you catch, is it not soft?—It is soft, but there is a little hardness in it, it is not as soft as the other water, it is rain-water of course.

5334. What does it pass through to make it hard?—I do not know why it should be hard.

5335. Have you had any analysis made of that water?—We had an analysis made two or three years ago, but it was with regard to a lawsuit that we were likely to have. I forget what the result of the analysis was, but a party was fouling the water with grease so that that analysis would not apply in this case.

5336. That analysis would detect the grease and not the lime, but was the investigation put in motion for the purpose of detecting the presence of grease, or was it with regard to the general qualities of the water?—It was put in motion for the purpose of detecting the presence of grease.

5337. Do you remember whether it was declared to be a hard water or a soft water?—No, but it could not have been declared a hard water, it has a certain

S. Jubb, Esq.

20 June 1867.

degree of hardness about it, but I cannot specify the amount.

5338. What is the character of the ground where this water is collected?—It is chiefly pasture land, the water runs off into a small rivulet or open drain.

5339. And that water is dammed up and settled?—Yes, it is collected in a dam and settled.

5340. (*Sir B. Phillips.*) Do you scour your own yarn when you buy them in the grease?—We do not scour the yarns, but we scour the cloth; we make up the yarns into cloth before scouring them.

5341. (*Chairman.*) What is your experience with regard to the use of what you call the towns water as compared with the water which you collect in the reservoir of which you have spoken?—We much prefer the towns water, it is far superior in all its effects, I mean both with regard to the saving of soap and with regard to producing brighter colour, and also it makes the cloth kinder, and at the same time I think firmer, so that it gives an advantage to the cloth as compared with the other water.

5342. Does it give it a mellower feel to the hand?—Yes, the cloth feels fuller in the hand, and at the same time it feels firmer.

5343. Is not it rather the result of the more perfect scour that you get rid of all the hardening effects of the manufacture by the use of soft water?—I think that may be so. I think the better you can get the grease out of the cloth, the cleaner it feels and the fuller it feels, and better in every respect.

5344. Have you instituted any inquiry for the purpose of ascertaining the relative saving by the use of the two waters?—I did put that question to our miller before I came away, and he told me that he thought that a saving of from 15 to 20 per cent. would be effected in the consumption of soap by the use of soft water as compared with hard water.

5345. (*Mr. Harrison.*) Is that in the mere cost of soap?—Yes, since we have used the towns water we have heard a great deal said about the great saving that was effected by the use of it, and therefore so I put the question to him. I do not know that we had ascertained it before.

5346. (*Chairman.*) What quantity of soap do you use in the course of a year?—About 800*l.* worth of soap.

5347. So far as your experience enables you to form an opinion, you would save about 120*l.* a year by the use of soft water as compared with hard water; that would be the absolute saving in the consumption of soap, but you would have the additional advantage of producing brighter and better colours, and cleansing your articles in order to give them a better handle, and thus enabling them to produce a better price when taken into the market?—Yes, it produces a superior cloth, there is no doubt about that.

5348. So that you could afford to pay a considerable sum for soft water for your manufacturing purposes?—We pay 6*d.* per 1,000 gallons for the towns water, and I should prefer to use it, I think, to having hard water at 3*d.* per 1,000 gallons or even 2*d.*

5349. Would you not prefer paying 1*s.* 6*d.* per 1,000 gallons for soft water for the purposes you have described, having regard to the saving that it effects?—We should not like to pay 1*s.* 6*d.* per 1,000 gallons.

5350. But supposing that it were a necessity and you could not obtain the water at a less price, would it not pay you as a manufacturer to give that price for it?—I do not know. I would not say even that it would not pay at that price.

5351. Supposing you could obtain hard water for nothing, would not it pay you to take soft water for manufacturing purposes even although you had to pay a considerable sum for that water?—That is a hypothetical question, and I should hardly like to answer it in the affirmative, but still I am not prepared to answer it in the negative.

5352. Have you any experience of the manufacture of the finer cloths at Huddersfield and Leeds?—I know in a general way the sort of cloths they produce.

5353. You do not use saxon wool, do you?—No, but we use Australian wool and colonial wool for the finer goods.

5354. Do you make flannels?—No.

5355. (*Sir B. Phillips.*) Have you any idea of what amount you pay for water?—Our last quarter's bill was 53*l.* for towns water.

5356. Is that the average; would you pay four times that in a year?—We are paying about 200*l.* a year now for water. We have not paid quite so much heretofore, but we have increased in the use of the towns water.

5357. How many hands do you employ?—From 400 to 500.

5358. (*Col. Harness.*) Could you say what proportion of that water is used for scouring?—It is nearly all used for scouring, we use very little for milling, the milling requires very little so to speak, the scouring the goods off is the process which requires a great quantity of water.

5359. (*Chairman.*) Is there any difference in the use of soft water as compared with hard for felting purposes?—Certainly; I think that the cloth is better felted by being scoured off with soft water. At least there is this property about the towns water, that I find the cloth is better felted after being scoured than it is when scoured by the other water. For a summer or two past we have run short of towns water, and we have had a good deal of goods to send out to other places to scour, where they have scoured them with hard water, and we have noticed that when the goods have been sent back they have been very much more slabby and loosely felted than our goods scoured with the towns water; they were not so firm to the hand.

5360. (*Mr. Prestwich.*) What distance are you from Leeds?—Eight miles south of Leeds.

5361. What is the nature of the supply to your reservoir?—It is from the country around; it is the watershed from off our local ground that flows into this dam.

5362. Is it a small stream that flows through your own grounds?—Not through our own grounds; it is a water right that we have.

5363. Is not the tract of country of a very similar nature to that from which the town supply is derived?—No, because all the water in the town supply falls on to moor land, on to the peat.

5364. Does the small stream from which you derive your other supply flow through a cultivated tract of country?—Yes, partly arable and partly pasture land.

5365. Does it pass through many villages?—No, it comes a very short distance. I should think it would not take its source more than a mile, if as much as a mile away.

5366. Is that water irony?—No; the water that we collect has a little hardness in it, but I do not know whether we should call it iron or not.

5367. You are probably not aware whether the hardnessis produced by iron, or by sulphate of lime, or carbonate of lime?—I am certain that there is no lime about it; it is not a lime district at all; it is a coal strata.

5368. The water simply falls upon the surface and runs off into a local stream, and you collect it at a certain point?—Yes.

5369. How can it, under such circumstances, be hard?—I do not see how it can have much hardness, but I was speaking to our dyer about it, and he said it was harder than the towns water.

5370. I suppose that some flowing water finds its way into that stream as well as the water that falls from the clouds?—Yes, there is a spring.

5371. (*Mr. Prestwich.*) Is there any source of impurity to that water?—Yes, there are sources of impurity, there is some sewage that flows into it.

5372. Is that found objectionable?—We do not like it, but we cannot help it.

5373. For your manufacturing purposes, would the presence of sewage injure the water?—Yes, I think it would be decidedly injurious.

5374. The water is not so clean as you wish it to be?—No.

5375. (*Chairman.*) Would the ammonia in that water have any effect upon your processes?—We use ammonia in dyeing.

5376. You use urine to a large extent, do you not, for cleansing purposes?—Yes, we do. We collect it in barrels; we send a man round with a barrel to collect it at different places.

5377. (*Mr. Prestwich.*) You have stated that your impression is that there is a saving of soap to the extent of 15 per cent.; is that impression derived from any direct experiments, or from a mere general opinion with regard to the matter?—I think that our miller has had so much experience in milling that his opinion would be about the mark. He has had several years' experience, and has been in the habit of using a great deal of soap, and I think that his estimate would be likely to be about correct.

5378. Can you give the Commission any opinion as to whether there is economy with regard to consumption of dyes in the use of soft water?—I understand that in some colours the use of soft water as compared with hard water does not effect any saving; for instance, in the case of blacks, but I think from what I can gather that upon the whole soft water is preferred for all colours.

5379. You have expressed an opinion that the use of soft water produces economy in the consumption of soap, and the object of my question was to ascertain whether there is also economy in the use of dyes?—Yes, I should say decidedly so, on the whole.

5380. (*Chairman.*) Independently of the production of a better colour?—Yes.

5381. Do you mean that the consumption of dyeing material would be lessened by the use of soft water?—That is my opinion without being able to state positively what the fact may be.

5382. You have been using the expressions soft and hard water, but you use them I presume relatively to the waters supplied by the town and the water which you collect from the stream?—Yes, we do not speak of them in a scientific sense or a chemical sense, but we speak of them as we find them adapted to our purposes.

5383. (*Sir B. Phillips.*) Do you know anything of silk dyeing?—No, I cannot say I know much of silk dyeing.

5384. (*Mr. Prestwich.*) Probably you heard the question which was put to the previous witness with regard to the circumstance that in the towns in France where they carry on dyeing of a similar class to that in which you and the other gentleman are engaged the water is chalk water of a hard quality?—I cannot understand how that should be. I should think that lime was antagonistic to our processes, either of milling or dyeing.

5385. But apparently you cannot support that opinion by any facts?—I know that we do not like lime, for lime is a very injurious thing in milling.

5386. I am speaking now merely with regard to colour not with regard to scouring. Are you acquainted with any facts as to the effect of lime upon colour?—I do not know that we have much experience with regard to lime water. I think our water is not impregnated much with lime but rather with iron; the water runs off the coal strata.

5387. (*Chairman.*) Would not the presence of lime give a very hard and harsh feeling to the fabric when made?—That is my impression. I think that lime is altogether antagonistic to softness in the cloth, or even to producing good colours; whether or not it may answer possibly for some colours I cannot say, as there is a great variety of colours. I know that formerly when we used our well water we could dye scarlets very well with it, but we could not wash them off, indeed the water turned them crimson. They could be dyed with the same water, but when they came to be washed off in the water they turned crimson. That arose from the presence of the iron in the water when it was used for scouring, but it would appear that in the dyeing the iron had been neutralized by some other agent.

5388. (*Mr. Prestwich.*) Is there any deposit of iron apparent in the streams or in the water channels?—No, I cannot say that there is in that channel which supplies our works.

5389. (*Chairman.*) Locally have you observed in the running streams any oxide of iron?—No, there is no ochrey water about us.

5390. (*Mr. Prestwich.*) Is there no analysis of this water that you can lay before the Commission?—No, I have not an analysis of our local waters at all, but iron is the principal ingredient I think that characterises the local waters; that is to say, the well waters which are pumped out from the ground.

5391. (*Chairman.*) Have you ever had any analysis made except for the purpose of the action to which you referred?—No, I believe not.

5392. (*Mr. Harrison.*) How far are you from the Low Moor ironworks?—About seven or eight miles.

5393. Do all those ironstone beds in that district extend through the hills to Batley?—I should think not.

5394. They are actually working the coal at Batley, and they have been getting the coal there for many years, have they not?—Yes.

5395. I believe that until they made the railway there the coal was not so extensively worked as it has been lately?—No, perhaps not, although I do not think there is much difference. There is a colliery opened at Morley which, no doubt, was principally opened on account of the railway, which is immediately adjoining us, but that is not in the township of Batley, it is in the township of Morley. We have coal about us in great quantities.

The witness withdrew.

JAMES ALFRED WANKLYN, Esq., examined.

J. A. Wanklyn Esq.

5396. (*Chairman.*) What position do you hold?—I am Professor of Chemistry at the London Institution, Finsbury.

5397. How long have you been professor there?—Four years.

5398. Has your attention been directed to the qualities of water?—It has.

5399. And to the qualities of the several waters supplied to the metropolis?—It has.

5400. Have you made any analysis of the water, or of all the waters?—I have examined several of the waters of the metropolis, but I have mostly examined artificial waters made by myself. Those were examined first, and then afterwards the waters supplying London were examined.

5401. Will you state to the Commission first, what was the result of your examination of the several waters supplied to the metropolis?—The result has been, that the New River water, as far as organic matter is concerned, is very fair, but the other waters are bad.

5402. Will you go on to describe the result of your examination of the water?—The Southwark and Vauxhall water is very bad indeed, it contains seven milligrams of white of egg in a litre; that is to say, the nitrogenous matter in an albuminous form (and in my report I mean to return the nitrogenous matter as albuminous matter or white of egg, and as urea). Those two kinds of nitrogenous matter are typical kinds, and they are good representatives of the different kinds of nitrogenous matter. The white of egg is the nitrogenous matter that forms the tissues, and is the undecomposed nitrogenous matter, and the urea is the tissues decomposed.

5403. Does the Southwark water contain a large proportion of this substance?—Yes, it contains a large

J. A. Wanklyn, Esq.

20 June 1867.

proportion of organic matter undecomposed, and it contains a small proportion only of organic matter decomposed to urea.

5404. Have you examined any other waters?—Yes, the New River water, and the water of the East London.

5405. What is the condition of the water of the East London?—The value is 3·2, the Southwark and Vauxhall value is 7·3, and the New River 3·0.

5406. There are two waters supplied to the East London district, which was your sample taken from?—It was taken from one of the street mains.

5407. Do you know the source of supply to that main?—I do not know the source of supply.

5408. How is that water, as compared with the New River and the Thames water at Thames Ditton?—It is very much better than the Thames water, and worse than the New River water.

5409. Then the New River water is superior to the Thames?—Yes, the New River water is superior to the Thames.

5410. Where did you take your sample of the Thames water from?—I had a great many samples of the Thames water. I cannot tell the exact point where they were taken, but a great number of samples of the Thames water have been taken.

5411. You did not take it I presume at London Bridge?—Water was taken from London Bridge, but samples were taken higher up.

5412. Did you take any of your samples above the tidal influence?—Yes, some samples were taken above the tidal influence, and other samples were taken below the tidal influence.

5413. You have drawn a contrast between the New River water and the Thames water. I want to know whether the waters which you so contrast were samples taken above or below Teddington lock?—I contrasted with samples both above and below Teddington lock.

5414. You are comparing a sample of Thames water with the New River water, where was the sample taken from?—The sample which I have compared with the New River water was a sample taken above Teddington lock.

5415. Was it taken at the point where the water companies take their supply. It is important that the Commission should know where the water was taken from, because even if taken above Teddington lock it might have been taken at a point where the sewage of Kingston might affect it very seriously?—I cannot give you the exact point.

5416. (*Mr. Harrison.*) Have you analysis of any of the London waters taken from any of the supply pipes in the streets?—Yes; in the case of the East London water the water was taken direct from the main. I have not the particulars here, but I can supply the Commission with the exact particulars.

5417. (*Chairman.*) Could you put in a table showing the result of your examination of the several waters, where the samples were taken from, and the date?—Yes, I will do so; the samples have all been taken recently, or within the last three or four days. That, I think, will be sufficient with regard to the date.

5418. Is there any other point to which you desire to call the attention of the Commission?—I should desire to say that my attention has been chiefly directed to perfecting a method of analysis, and the method has only just been made sufficiently perfect to be worked. I have been operating upon artificial waters with the view of testing the method, and I have not had time or opportunity for giving the method a fair chance at present. There is one point to which I should like to direct attention. There is a passage in a report, dated 1856, on the metropolitan water supply, by Professor Hofmann and Mr. Blyth, which explains very well what has recently been done. "Very little is known "of the nature of the ill-defined substances which "constitute the organic matter generally found in "water. Berzelius distinguishes two substances, "crenic and apocrenic acids, which slightly differ in "their chemical deportment, but these two bodies are "as yet scarcely chemically examined, and much "doubt still hangs over their individuality and even "over their existence. The organic matter in water "has been divided into nitrogenous and non-nitrogenous matter, but all we know is that certain "varieties of the organic matter found in water contain nitrogen, which is readily shown by treating "them with hydrate of potash, when abundance of "ammonia is evolved. The opinions of chemists are "divided as to the manner in which organic matter "in water is capable under certain conditions of producing a deleterious effect upon the animal economy. "But it is now generally admitted that the substances "which constitute the organic matter of water act "injuriously, by no means in consequence of being "poisonous themselves, but by undergoing those great "processes of transformation called decay and putrefaction, to which all vegetable and animal matter "is subject when no longer under the control of "vitality, either in plants or animals. These putrefactive processes either give rise to the formation "of poisonous bodies or they act simply as ferments, "generating similar processes of decomposition in the "substances composing the animal organism. Now, "with special reference to the last mode of action, "it is well established by general experience that "nitrogenous substances are infinitely more liable "to undergo putrefaction than organic bodies from "which nitrogen is absent," showing that Professor Hofmann thought, and it is generally admitted that the nitrogenous organic matters alone are those which we have any need to pay attention to. "And hence "the very general and correct opinion that the "deleterious character of organic matter in water is "proportionate to the amount of nitrogen which it "contains. Could this nitrogen be estimated with "any degree of accuracy, such an estimate would "certainly afford the most satisfactory element in the "examination of the organic matter. Unfortunately "this estimate is attended with very considerable "difficulties. The nitrogen of the organic matter "which has undergone putrefaction and has therefore ceased to be deleterious remains in the water, "partly as ammonia, partly as nitric acid. It would "therefore by no means be sufficient to evaporate the "water and to determine the amount of nitrogen in "the residue. It would be absolutely necessary to "estimate also the nitrogen present in the form of "nitric acid and of ammonia, and only after the "deduction of their joint amount from the total "amount numbers would be obtained which, representing the quantity of still putrescible nitrogenous "substances, would afford within certain limits the "necessary data for a comparison of the organic "matter present in different waters. It is obvious "that this mode of proceeding is very complicated, "and not likely to furnish trustworthy results unless "carried out with the greatest circumspection, and "with all the appliances which the modern progress "of analytical chemistry can suggest." I have to remark that the method of determining the organic matters which I use is a very simple one,* and can be carried out in about three hours, and the determination is a perfectly direct one. I do not determine the total nitrogen in a water and then determine the nitrogen present as ammonia and nitric acid and give you the difference, but I determine directly the nitrogen present as organic matter, and that you will see is an important thing. The project of 10 years ago, (and it has been tried to be carried out, and it is admitted that it will be very difficult to carry it out,) was to give you the organic matter by a double process, giving you a difference; but my method is a

* The method of determining organic nitrogenous matter here referred to is the joint discovery of Messrs. E. T. Chapman, Miles H. Smith, and myself.—*Vide* "Laboratory," weekly journal.

All the experiments referred to were made in the laboratory of the London Institution, in many cases by Messrs. Chapman and Smith.—J. A. W.

direct one. I give you directly the nitrogen which is present in the organic matter. And there is another point which should also be mentioned. It is necessary to examine water fresh, and not after it has been kept a day. I had an example in which I examined a London water immediately it was taken, and then examined it 18 hours afterwards and I found a very perceptible difference.

5419. (*Mr. Harrison.*) Were the samples hermetically sealed in both cases?—The water was taken in a Winchester quart bottle and immediately examined, and a portion of the water in the Winchester quart bottle was kept till the next day and was examined again, and there was a very sensible difference. It was not sealed, but simply stoppered.

5420. I presume you have been on a matter of such vast importance in communication with Dr. Frankland?—I spoke almost daily to Dr. Frankland about it for some time.

5421. You are aware, are you not, of the monthly reports which Dr. Frankland makes, and the analyses which he gives of the London waters?—Yes, I know them very well.

5422. Is the conclusion which you have arrived at that those results are not sufficiently satisfactory?—I believe that they have no value whatsoever as regards the organic nitrogenous matters.

5423. Having been in consultation with Dr. Frankland, can you tell us what he thinks of your process?—He has admitted to me the extreme value of the process.

5424. He has not yet adopted it, has he, in his analyses?—He has made experiments upon it. I am not aware that he has as yet adopted it, but he has admitted to me that it is the process. I may mention that Professor Way has adopted my process, and is working it.

5425. (*Mr. Prestwich.*) Has not Dr. Frankland, in the results which he has given for the last two or three months, introduced a new method of analysis?—His method is literally carrying out what Professor Hofmann sketched out in his report. He gave you the organic matters by this method.

5426. He determined the total quantity of nitrogen, and then apportioned a certain quantity of it to nitrates and nitrites and a certain quantity to ammonia, and he took the difference, I think, as the organic matter?—Yes. He gives you the total nitrogen in water present as nitric acid and ammonia, and determines the organic nitrogen, but Dr. Frankland himself admits that the method is unsatisfactory to the last degree.

5427. Still Dr. Frankland thinks it is the best mode within his knowledge of obtaining the desired result?—It was the best mode and the only mode known at the time.

5428. I presume that he considers it the best mode now known, inasmuch as he still continues to give the results obtained by such a method. In what way does your process differ? I mean, what is your mode of conducting the analysis for organic matters?—The mode is this: I take the water and boil it with carbonate of soda, and I take a litre of water, and I first collect a third of the distillate. In that distillate there will be all the nitrogen that was present as ammonia and as urea. I then add caustic potash and permanganate of potash and distil, and the second distillate contains all or very nearly all the nitrogen that was present as albumen. I may mention that under the term albumen I mean albumenoid matters. I have made this experiment. I have taken a certain quantity of white of egg, and weighed it and put it into a water and obtained very nearly all the nitrogen that it contained in the form of ammonia, and that is the most direct evidence that could be had.

5429. To what extent does the application of your process and that of Dr. Frankland's differ in their results; that is to say, supposing you take an analysis of the London waters as given by Dr. Frankland in any given month, he shows that there is a certain amount of nitrogen present in the ammonia, a certain quantity of nitrates and nitrites, and a certain quantity derived from—I think he terms it—sewage matter. What is the difference in the results obtained by the application of your method?—We get the nitrogen that is present as urea and as albumen, and Dr. Frankland's method really does not give that at all. In evaporating the water down to dryness, in order to get the residue, the urea is lost; it is converted into ammonia in great part, so that Dr. Frankland's first value for total nitrogen is defective. If Dr. Frankland's method were good it would be necessary that his determination of total nitrogen should be good, and that his determination of nitrates and ammonia should be good. The total nitrogen is taken from the nitrogen in the residue; now before you can get the residue the greater part of the urea is lost. I tried an experiment in which I took a litre of water and put into it a gramme of urea and evaporated it down. I did not get more than a decigramme of urea left.

5430. Do the results of your analyses give a larger quantity of free organic matter present in water?—Yes, a larger quantity;* and Dr. Frankland's organic nitrogen is totally irregular, for the method is not even regular.

5431. Can you tell us what the extent of difference is between you and the returns published every month by Dr. Frankland?—I will put in tabular forms of the analyses. The method is quite new, and that will account for the fact that I have really no adequate set of analyses of the London waters.

The witness delivered in the following tabular statement:

TABLE I.†

SOME WATERS used for the ORDINARY SUPPLY of LONDON.

Date when taken.	——	Parts in 1,000,000. I. Ammonia originally present, and from Urea.	II. Ammonia from Albumenoid Matter.	III. Moist White of Egg.
19 June	New River, from cabstand near Moorgate Street railway station.	Not taken.	0·090	3·213
21 June	Water from same place.	0·015	0·084	2·999
18 June	East London, water from cabstand in Whitechapel.	0·030	0·089	3·177
19 June	Southwark and Vauxhall, cabstand near London Bridge.	Not taken.	0·206	7·359
21 June	Same, taken from same place.	0·039	0·204	7·283

TABLE II.

WATERS from PUMPS in or near the City of LONDON.

Date when taken.	——	Parts in 1,000,000. I. Ammonia original, and as Urea.	II. Ammonia from Albumenoid Matter.	III. Moist White of Egg.
28 June	Pump in Bishopsgate Street opposite Houndsditch.	7·500	0·255	9·004
27 June	Pump in Bartholomew Lane (east end of the Bank of England).	5·500	0·240	8·568
21 June	Pump in Great St. Helen's.	3·750	0·180	6·426
28 June	Pump in St. Paul's Churchyard, north side.	0·060	0·135	4·819

* The analyses referred to are the March analyses.—J. A. W.

† The analyses given in these four tables were made in the laboratory of the London Institution by E. T. Chapman, M. H. Smith, and myself.

TABLE III.

WATERS from VARIOUS SOURCES.

Date when taken.	——	Parts in 1,000,000. I. Ammonia original, and as Urea.	II. Ammonia from Albumenoid Matter.	III. Moist White of Egg.
June 18	High tide. Thames water direct from river at London Bridge (filtered).	2·040	0·590	20·963
„ 19	One hour flood. Same. Thames.	2·200	0·500	17·850
„ 27	Same sample kept in stoppered bottle. Thames.	1·500	0·390	13·923
„ 26*	Loch Katrine, from main in Glasgow.	0·020	0·130	4·641
„ 27	Samaritan Company's water, Wapping.	0·060	0·150	5·355
„ 27	Bucks Hill spring, Kensington Gardens.	0·030	0·150	5·355
„ 22	Wolsey's well, Wimbledon Common.	0·030	0·159	5·676
„ 24	Artesian well, Bank of England.	0·600	0·030	1·071

* Analysed 27th June

TABLE IV.

WATERS free from ORGANIC MATTER containing NITROGEN.

Date when taken.	——	Parts in 1,000,000. I. Ammonia originally present.	II. Ammonia as Albumenoids.	III. Moist White of Egg.
	Distilled water, distilled in the laboratory of the London Institution.	0·060	0·000	0·000
June 24	Water from Cold Harbour, Dorking, (from the green sand).	0·015	0·000	0·000
„ 25*	Caterham water, from waterworks, after Clarke's process.	0·040	0·000	0·000

* Examined June 26th..

NOTE ON THE TABLES.

Column I. contains the ammonia originally present in the water, and also the ammonia derived from the decomposition of urea.

Column II. contains the ammonia derived from the decomposition of albuminoid matter.

Column III. contains the amount of albumenoid matter expressed as white of egg (moist), and is calculated from Column II. This column is inserted in order to give some idea of the amount of organic tissue to which the albumenoid ammonia would correspond. The data for this calculation have been furnished by an analysis of white of egg undried and fresh. 2·80 parts of ammonia correspond to 100 parts of white of egg.

REMARKS ON THE TABLES.

Table I. If Dr. Frankland's published tables of London waters be examined, it will be seen that four out of the eight London waters were free from "organic nitrogen" in February, that in March all the London waters were free from "organic nitrogen," and that in May all were rich in "organic nitrogen," the New River being the worst. This calculation is made according to Hofmann and Blyth's rule, by subtracting from total nitrogen the sum of the nitrogen present as nitric acid, nitrous acid, and ammonia. It will be observed that there is a total want of agreement between these results given by Dr. Frankland and those which I have the honour of presenting.

According to Dr. Frankland's May table, "New River contains ·076 parts of" organic nitrogen in 100,000 parts of water. This is equal to rather more than 0·760 parts of albumenoid *ammonia* in 1,000,000 parts of water. We obtain 0·090 and 0·084 parts of albumenoid *ammonia* in 1,000,000 parts of New River water taken in June.

Table II. I have to call attention to the horrible state of the first three pumps.

Table III. I have to notice that Thames water taken from the river at London Bridge is better in regard to "organic nitrogen" than Dr. Frankland's May table represents New River water to have been. The third Thames water which had been kept for some days illustrates the alteration which a very bad water may undergo on keeping.

I beg to call attention to the fact that "Loch Katrine" water is inferior, organically considered, to New River water.

Table IV. shows that there are spring waters which are absolutely faultless in regard to organic nitrogen. I have to add that in my opinion it will not be difficult to find many such spring waters, and that the water of lakes and rivers is not the best that can be found for the purpose of supplying towns with drinking water.

5432. (*Chairman.*) Have you had any discussion with Dr. Miller upon this point?—I have spoken with him and he thinks my method promises well.

5433. But he has not adopted your system, has he?—The system is only a few weeks old, and I cannot tell whether he has or not, but Professor Way is adopting the system.

5434. Professor Way is now examining the London waters, is he not?—Yes, I think so.

5435. And is he adopting the system which you propose in the examination of those waters?—Yes.

5436. (*Mr. Harrison.*) It is only, as I understand, within the last week or two that you have arrived at a positive result in those experiments?—The method is about a month old; that is to say, about a month ago I was certain that the method was workable, but it is only within the last week or two that little difficulties of detail have been got over; in fact, it is only just now that the method is in that perfection that it can be used.

5437. (*Chairman.*) What is the saving in time in making an analysis of water by your system as compared with the old system?—I can make a determination of the organic matter in water in a couple of hours with ease, and I cannot make a determination by Dr. Frankland's method under two days. I have myself made determinations by Dr. Frankland's method; in fact under his own eye almost.

5438. Have you made an examination of the same water and compared the results?—In one instance I did.

5439. What was the result of that comparison?—Part of the result of the comparison was this, that some of the nitrogen which he returned as ammonia originally present I return as urea, and also that I get a certain value for the albumenoid nitrogen, whereas Dr. Frankland gets no certain value for it. But the difference in the ammonia obtained as such is probably due to this cause, that the water which I operated upon was examined immediately I got it home, or within an hour or two of its being taken, and Dr. Frankland's would be kept a day or two first.

5440. (*Mr. Prestwich.*) During which time a change goes on in the water, which produces ammonia?—The urea becomes ammonia, and carbonic acid and the albumenoid nitrogen is changed also.

5441. (*Chairman.*) Has your attention been directed to the question of constant supply of water as compared with the intermittent system now in operation?—I have not paid any attention to that subject.

5442. Do you think that for purposes of health water taken immediately from a pipe would be preferable for drinking to water taken from tanks, or vessels of any kind in which it might have been stored in a house?—There is no question that small cisterns in houses are very bad indeed. I can mention a fact upon that subject which is of importance. The New River water was taken directly from the main and examined, and there was only a trace of albumenoid matter in it, but some New River water

was kept in a cistern in my own laboratory, which is rather a damp laboratory, was examined, and there was found in it a sensible quantity of albumenoid matter. I am sure that keeping water in cisterns tends to generate this albumenoid matter; I should mention, however, that this cistern has not been cleared for years.

5443. (*Mr. Prestwich.*) Have you tested for the presence of organic matter in any of the spring waters round London?—Not in any of the spring waters round London, but I have made examinations of water from some of the springs in London itself; from the pump in Berkeley Square, for instance, and from a pump somewhere in the East of London, which was a wretched water indeed.

5444. But have you examined the water of springs from any part of the chalk, for example the springs at Grays, or the springs in the valley of the Lea?—I have not examined them.*

5445. Have you examined the water of the artesian wells in London?—Not yet.

5446. (*Mr. Harrison.*) You have made an analysis of the Southwark and Vauxhall water, have you not, and you say that the quality of that water is bad?—It is very bad.

5447. Was that water taken from their mains?—Yes, it was Thames water taken direct from the main.

5448–49. How does that analysis agree with Dr. Frankland's, who has reported in the last monthly report that he considers all those waters perfectly innocuous?—In the one that I refer to,† Dr. Frankland returns rather a higher value of ammonia present as ammonia, and I return a lower value of ammonia. Then I return a quantity of nitrogen present as albumenoid matter, and I believe Dr. Frankland returns no organic nitrogen at all. I have not Dr. Frankland's analysis to refer to at the moment, but as far as my memory serves me, Dr. Frankland returns no organic nitrogen in the water, and I return two decimillegrammes of ammonia per litre, or calculated into white of egg, 7·3 millegrammes of white of egg; that is to say, of albumen, reckoning it in a wet state just as you get it out of the egg. I made analyses of the white of egg as it is in the egg, without any drying or anything of the kind, in order to determine the nitrogen directly by the ordinary method, so as to have a term in which to express this organic matter.

5450. (*Mr. Prestwich.*) You merely use it as a term of comparison?—Merely as a term of comparison.

5451. (*Mr. Harrison.*) What is the result which you have arrived at as to the wholesomeness of that Southwark and Vauxhall water?—It must be very dangerous. I have no doubt whatever that it is dangerous, for this albumenoid matter may be organic germs of all kinds, and, in fact, the very worst things that there could be in a water. There is a point which ought to be mentioned. What are supposed to be the worst things that can be present in a water are germs that may set up a kind of vegetation within us, and if there are any of those germs in a water the albumen in the germs will be converted into ammonia by this process of analysis of mine, so that there is an actual measure of the possible amount of germ.

5452. (*Mr. Prestwich.*) How can you distinguish between that which is converted into ammonia and the ammonia originally present in water?—If there is ammonia originally present it distils over with the first third of the water, if you put carbonate of soda into it. Those germs are pretty stable, and they are only broken up completely by potash and permanganate of potash. I made an experiment with distilled water, and distilled with potash and permanganate of potash, and got no trace of ammonia after removing the trace of ammonia originally present. I have taken a water into which albumen had been put, and put in some carbonate of soda, and distilled and got off traces of ammonia. I put in potash and got off traces of ammonia, and I then added permanganate of potash and got a quantity of ammonia. I have taken distilled water and put into it a weighed quantity of white of egg, and got out all the nitrogen in the form of the ammonia.

5453. Are you sure that you can separate the ammonia originally present in water from the nitrogenous matter?—Yes, I have no doubt whatever on that point. I am quite certain of it. I made an experiment in which I put a hundred times as much ammonia into a water as can be present in a natural water, and distilled over, testing the first distillate, and by the time the water had been half distilled over there was no ammonia. The test which I use for ammonia is Nessler's test; it is a test of extraordinary delicacy, and I never test for albumen until I have first distilled off at least one-third of the water with carbonate of soda, and until the distillate gives no reaction with Nessler's test. I have never given the value for albumen unless I have first completely cleared the water of any ammonia by boiling it with carbonate of soda, and a water which will allow you to distil it from carbonate of soda without giving that which will affect Nessler's test is free from ammonia.

5454. Those analyses of organic matter are analyses of very great delicacy and difficulty, are they not, and there is great difference of opinion among chemists with regard to the best mode to be adopted?—There has been great difference, but I do not apprehend that there will be any longer any difference when our method is fully known.

5455. But that method is not yet fully known?—It is not fully known, this evening I am about to read a paper on it at the Chemical Society, and this paper will be the first complete publication of the method.

5456. (*Mr. Harrison.*) Have you applied your method to any of the pure waters?—I have applied it to distilled water, which is the only pure water.*

5457. I mean to any soft water?—No, not to any soft water. I have applied it to distilled water, because for the method to be worth anything it must give no reaction with distilled water, and my method has given nothing with distilled water; it has given a slight indication of albumenoid matter even with the New River water.

5458. Do you consider the New River water from that analysis to be a perfectly good and wholesome water?—I could not say so; it certainly contains a trace of albumenoid matter, but it is the water that contains the least of the London waters.

5459. But do you know of any water that has been submitted to your process which would contain no trace of it?—I have not examined any water from the country so that my opinion really is not of very much value upon that point. Distilled waters give no trace of albumenoid matter, but I have never examined by my method any of the waters which are reported as being extremely good waters.†

5460. (*Mr. Prestwich.*) Then you do not agree with Dr. Frankland that by the time the Thames water or the New River water is delivered in London, after having passed through the filtering processes, are so far oxydised as to have all the organic matter converted into nitrates and nitrites of ammonia?—I am sure that that cannot be so, for I have obtained this reaction for albumenoid matter in those London waters, and the test is this. The water is mixed with carbonate of soda and a distillate taken, and when the distillate shows no sign of ammonia by Nessler's test, then potash and permanganate of potash are added, and the appearance of ammonia is a sign of albumenoid matter.

5461. (*Mr. Harrison.*) How long is it since you communicated with Dr. Frankland upon your method?—Within the last week.

* Since giving this evidence different waters have been examined.—*Vide* Report sent in.—J. A. W.

† The March table of analyses was referred to.—J. A. W.

* *Vide* Report.—J. A. W.

† Since giving this evidence I have found some waters quite satisfactory.—J. A. W.

J. A. Wanklyn, Esq.

20 June 1867.

5462. Has he been present when you have gone through the whole process?—He has never seen the process worked in my laboratory, I have never made any experiment before him.

5463. In the case of Professor Way, have you gone through the whole process with him, or merely described it to him?—Not to him, but I know that his assistant is practising the method.

5464. You are not able to say whether you have as yet found any waters that are perfectly free from organic matter?—I have found distilled water free from albumenoid matter, but I have really never examined any of the reputed good waters, and therefore I cannot say whether they contain albumenoid matter or not.*

5465. (*Mr. Prestwich.*) Might not this albumenoid matter be derived from either vegetable or animal substances?—Yes, precisely.

5466. Therefore it would not necessarily be an indication of sewage contamination?—No. The indication of sewage contamination is the urea reaction. Urea gives up all its nitrogen in the form of ammonia by distilling with carbonate of soda alone, but albumen does not give up any of its nitrogen with carbonate of soda alone, but only with potash and permanganate of potash; so that I can distinguish between urea and albumen. If you put into one water a little urea, into another a little urea and albumen, and into a third albumen only, I could return the one as urea, the other as a mixture, and the third as albumen.

5467. Can you determine separately the quantity of ammonia, the quantity of urea, the quantity of albuminous matter, and the quantity of nitrates and nitrites?—The quantity of nitrates and nitrites does not enter into my method; that is to say, I do not give you the value in nitrogen, but always in ammonia, and my reagents do not convert nitrates and nitrites into ammonia.

5468. How do you account for the nitrogen present in the nitrates and nitrites?—I account for it in this way—it comes partly from atmospheric nitrogen which has been oxidised, and partly, I believe, from the chalk itself; for there is no doubt that chalk contains nitrogen, and also from sewage if that be present.

5469. Does not the presence of nitrogen in the nitrates and nitrites interfere with your method in any way?—Not in the least. I give a direct experiment in which I put nitrate of potash and nitrite, and there is no interference.

5470. You say that there is a certain quantity of albuminous matter present in the New River water; do you find that there is any free urea?—It is questionable. The quantity is very minute, indeed so minute that it is questionable whether there is any; but of albumenoid matter there is certainly a little.

5471. And in other London waters have you detected any?—In some of them there is what may be a larger quantity of albumenoid matter, and in others less.

5472. Do you find urea in them?—I find urea in small quantities only, and so small as to render it uncertain. When the quantity falls below a certain mark you cannot be absolutely sure whether there is any at all. The quantity of urea in the London water is, as a rule, very minute, so minute that it is hardly possible to say whether there is any or not.

5473. Has not albuminous matter been, I believe, found even in the deepest spring water where you would not suspect the presence of any organic matter?—Possibly that may be so, but I have made an examination of water from a London well and the water is wretched to the last degree, in the sense that it contains nitrates and nitrites of ammonia present as such, but it does not contain more than traces of albumen or traces of urea.

5474. Do you know what well it was from which that water came?—It is a well somewhere in the east of London.

5475. Is it an artesian well or a surface well?—A surface well, and the supply is really from a graveyard. It was taken as an example of very bad water indeed, but strange to say it was not found to be so bad as might have been expected. The total amount of nitrogen in it was enormous, but it was chiefly present as nitric acid and ammonia, and there were only traces of the other matters.

5476. (*Mr. Harrison.*) What do you assume to be the source of such albumen as you find in those waters?—A part of it would be sewage. I should say that the source is sewage in the case of the London waters.

5477. (*Mr. Prestwich.*) But you stated just now, did you not, that you could not distinguish whether the albumen might have been derived from animal matter or from vegetable matter?—Yes, it cannot be said at all with certainty.

5478. Therefore it would not be a necessary conclusion that it would be from sewage?—No, not at all.

5479. (*Chairman.*) Then you do not entertain the opinion that the sewage discharged into a river at point A, and carried down the stream for two or three miles, would be so broken up as to lose its deleterious properties?—No, I am sure it would not. All the urea that is in it is for the most part decomposed, but the albumenoid matters are not decomposed, and those you will get.

5480. Then all waters used for domestic purposes you assume should be intercepted?—Certainly.

5481. And that no length of time or volume of water would destroy the evidence of pollution which you have described?—Nothing that is practicable.

5482. It has been stated in evidence before us that if you pour into water a volume of sewage equal to five per cent. of the volume of water into which it is cast, the water will so operate upon it in deodorising and destroying and breaking up its elements into its primitive elements in fact, that it would no longer be sewage or possess any of its noxious qualities. You apparently hold a contrary opinion?—This I am sure of; the urea in the sewage in such a water would be very readily broken up into ammonia and carbonic acid, and a little exposure would dispose of the urea, but the albumenoid matter in sewage is extremely persistent, and one of the results of the whole investigation is this, that albumenoid matter is very persistent indeed, and you could not depend upon any treatment such as you have mentioned getting rid of the albumenoid matter.

5483. It was stated further in evidence that of the sewage discharged at Windsor, for example, no traces can be found three miles below Windsor?—I am sure that is incorrect. I am sure I could find out albumenoid matter in it.

5484. (*Mr. Prestwich.*) Supposing you extend the length of flow from three miles to 20 miles, what would be the result?—I have not made a direct experiment upon that point, but in my opinion you would get rid of all the urea, but you would still have the albumenoid matters.

5485. But will not certain changes take place, even in the albumenoid matters?—Yes, certainly; but the change is very slow, and it is very irregular. The change in urea is very rapid, so that you have to operate upon water recently taken in order to get your full quantity of urea.

5486. How do you account for the fact which you just now mentioned, that in the well in the east of London, into which the drainage from a churchyard passed, the albuminous matter and the urea had been so much got rid of that there were hardly traces of them remaining?—I imagine that what would leave the graveyard would be chiefly urea, and not albumenoid matter; but of course it is an ancient graveyard.

5487. Still, in the case of all the water from the shallow well springs in the east of London, the gravel is so permeable that it is charged with organic matter of all sorts?—In the case that I mentioned one would

* *See* Report.

think that all the albumenoid matter which would easily pass into solution would have passed away long ago, and now one is getting the urea, and in fact the products of the decomposition of masses of albuminous matter.

5488. Have you paid attention, in a sanitary point of view, or with regard to its application to manufactures, to the relative advantages of the use of soft and hard water?—Very little, but I have paid a little attention to it. I have no doubt that soft water is preferable to hard.

5489. You have mentioned that in a cistern exposed in your laboratory a larger quantity of nitrogenous matter was found to be present than in the water taken from the main?—Yes, of albumenoid matter, and I imagine that the source of it was vegetation actually in the cistern.

5490. Are you of opinion that water so exposed in cisterns in private houses, or in courts, or elsewhere, whether soft or hard water, would become rapidly contaminated by the presence in the air of any offensive matters?—I have no data to form an opinion upon that point.

5491. When you say that you think soft water would be preferable water to use, upon what do you ground your opinion?—It will wash more perfectly than hard water will. Practically you cannot wash yourself with hard water.

5492. But what is your opinion with reference to its qualities as a drinking water?—I think there are no data to show that it is preferable as a drinking water to hard water.

5493. With regard to washing water, we have had evidence of the economy of soft water, and with regard to its use in manufactures, I think you were present when the two previous witnesses gave their evidence with respect to the use of water in dyeing and scouring; do you agree in opinion with those witnesses?—I have had some experience in manufacturing chemistry, and I can answer with certainty that soft water is far preferable to hard for dyeing.

J. A. Wanklyn, Esq.

20 June 1867.

5494. May I ask you upon what your opinion is founded?—You get much more regular results, and the colour is more soluble.

5495. Have you ever made any experiment or investigated the subject in any towns where dyeing is carried on?—I have not made experiments directly to determine that point, but in dyeing it is of great importance that the colour should remain in solution as perfectly as may be, and any precipitation of carbonate of lime carries down some of the colours, and the bath becomes irregular directly. I know as a fact, that in making specimens for dyers, it is desirable to use distilled water.

5496. But you have no direct knowledge yourself with regard to the use of it, either by experiment or by the experience of manufacturers?—I have only a general experience with regard to it. Perhaps I may be permitted to observe, with respect to my difference of opinion from Dr. Frankland on the subject of the analysis of water, that there have been several discussions between us at different times. There was a question between us about the validity of a test, and he now admits that the test is invalid.

5497. (*Mr. Prestwich.*) Was that the permanganate of potash test?—It was a test for nitrates. Dr. Frankland's method depends upon the double determination of nitrogen, the determination of the total nitrogen, and the determination of nitrogen as nitrates and nitrites. It has been shown that the Pugh test totally fails, and Dr. Frankland now admits that it totally fails.

The witness withdrew.

Adjourned to Thursday next at 11 o'clock.

Thursday, 27th June 1867.

PRESENT:

SIR JOHN THWAITES IN THE CHAIR.

Alderman Sir BENJAMIN PHILLIPS.	THOMAS ELLIOT HARRISON, Esq.
Colonel HARNESS.	JOSEPH PRESTWICH, Esq.

JOHN ROBINSON MCCLEAN, Esq., examined.

J. R. McClean, Esq.

27 June 1867.

5498. (*Chairman.*) You are a civil engineer, as we all know, and past President of the Institute of Civil Engineers?—Yes.

5499. You have I believe directed your attention to the question of an improved water supply to the metropolis?—I have for upwards of 20 years.

5500. In 1849 you had some plan, had you not, for the supply of London?—Yes, a company at that time deposited plans during two sessions for the improvement of the supply of water to the metropolis. (*The witness delivered in a plan and section; see Appendices T (1) and T (2).*

5501. Were you before Parliament with that plan?—We were twice, but it was thrown out on second reading the first time and stopped on Standing Orders the second time. It was never examined before any committee.

5502. Was the opposition promoted by the existing companies, or how do you account for the rejection of the scheme?—At that time there was a great clamour for an improved supply of water, and a number principally of professional men formed themselves into a company for the purpose of improving the supply, but the result was that the existing companies improved their supply, and our scheme was of course set aside.

5503. They went into Parliament after that attempt at legislation, did they not?—They did; the Act of 1852 was obtained, which was a compromise.

5504. You spurred them up to that state of activity?—We hope so.

5505. There was a general agitation, I believe, at that time, throughout the metropolis for an improved and constant supply of water?—There was.

5506. And there was considerable discussion as to the possibility of obtaining a sufficient supply from the chalk at Watford?—There was.

5507. Will you be good enough to describe to the Commission the general features of your plan which was before Parliament in 1849 and 1850?—It was proposed to take the water from the catchment basin of the Thames above Henley-on-Thames. The drainage area above Henley Lock is 2,500 square miles, or 1,605,000 acres, or equal to one-twentieth part of the area of England.

5508. When you speak of that area you mean that part of the Thames watershed west of Maidenhead?—Yes, above Henley and Oxford on the one side and the river Kennet on the other.

5509. Therefore it is above the point where you tap the Thames?—Yes, it takes in both the Loddon and the Kennet, but leaves out several of the streams which fall into the Thames below. The annual rainfall over this district is about 26 inches.

5510. How do you ascertain that?—We ascertained it from Mr. Blackwell, the engineer of the Kennet and Avon canal, who had very accurate gaugings made for

J. R. McClean, Esq.

27 June 1867.

several years, and the result was that the mean rainfall was estimated at 26 inches; of course it could only be an estimate.

5511. Do you remember the number of years that those gauges were down?—I do not, but I can give the whole of the gaugings if required.

5512. Were there a sufficient number, as far as your memory serves you, to give anything like a fair estimate of the amount of rainfall?—Yes, I believe so.

5513. And this is the mean of the several gaugings?—Yes, this is the mean.

5514. (*Mr. Harrison.*) Mr. Blackwell was for many years engineer of the Kennet and Avon Canal, and it was during that period that he had taken observations?—It was; and his father was engineer before him, so that he had very great experience. He was joint engineer with me in this project, but he is since dead.

5515. (*Chairman.*) You book 26 inches as the mean rainfall, and did you take any gaugings of the river at the point where you propose to tap it, or at any other point, so as to enable you to judge of the net result of that rainfall in passing any given point of the river?—Yes, we did. Mr. Blackwell, during one of the driest seasons at that time on record gauged the weir of the Henley reservoir or basin.

5516. Was it in a condition to enable you to make an accurate gauge?—Yes.

5517. Is it not very much out of repair?—Yes, very much, but it was in a sufficient condition to enable him to gauge. During the driest season not less than 345,000,000 gallons passed through the Henley Pond on any day. Mr. Blackwell states that quantity was the minimum of the gaugings, taken near the termination of an unusually long protracted season of drought, that was in the year 1848–49.

5518. How long after it has ceased raining is the effect of drought shown on the river by a diminished quantity of water?—It depends on the rainfall.

5519. Do you know whether the gauging at the Henley Weir was made a sufficient time after the fall of rain really to be called a dry weather drought gauging?—Yes it was. Both Mr. Walker who reported on the whole subject for the City of London and Mr. Leach adopted those figures.

5520. Some time after the rainfall the water will flow into the Thames in abundance?—Yes. If you will allow me I will read what Mr. Blackwell says about that. "Now over this district the average "annual fall of rain is 26 inches, of which experiment "has shown that one-half is evaporated or permanently "absorved, leaving a depth of 13 inches as the quantity "which passes down the river at Henley. This "total quantity we may expect, therefore, to be "75,751,983,450 cubic feet," or, on an average, 1,300,000,000 gallons daily.

"But it will be obvious that a very large portion "of this runs to waste in floods in the winter, and "the practical question becomes how much we may "expect to find in the river in any particular month "of the year; and the solution of this will depend "on the geological formation and the nature of the "soils of the district drained. If the soil is either "a hard rock, or impervious clay, the rain cannot "penetrate, and rushes off to the brooks and rivers "immediately on falling, accelerated or retarded, "of course, as the slopes of the hills are greater or "less. If on the contrary it is of a porous character "the rain water percolates slowly through, and it is a "long time before it feeds the streams. Now the "district which is the great receiver of our supply is "essentially of the latter character as the following "geological divisions in which I use Dr. Smith's "nomenclature will show."

		River Loddon.	Kennet.	Isis and Thames.
		Acres.	Acres.	Acres.
Tertiary.—Sand and gravel, with sandstones and a little clay		164,615	101,760	130,560
Cretaceous.	Gault brick-earth	- -	- -	45,440
	Blue Marl	- -	- -	63,360
	Chalk	8,320	192,000	173,440
Oolitic.	Oaktree Clay	- -	- -	122,240
	Coral Rag Limestone	- -	- -	44,160
	Sand and Sandstone	- -	- -	49,280
	Clunch Clay and Shale	- -	- -	140,160
	Cornbrash	- -	- -	74,880
	Forest Marl	- -	- -	45,440
	Oolite	- -	- -	234,240
	Brown Marl	- -	- -	15,360
	Total, 1,605,256 acres	172,936	293,760	1,138,560

"In a geological point of view the river Thames is, "of all the large rivers of England, that in which we "may expect the slowest and most constant influence of "the rain that falls. From the basins of its tributaries, the rivers Kennet and Loddon especially, "consisting as they do almost entirely of chalk or "other pervious subsoil, the water finds its way very "slowly; and it is not until after many weeks of "drought that any diminution of the quantity "they supply is perceived."

"The results of my own carefully repeated "experiments quite agree with the conclusions that "a scientific consideration of the above data would "lead to. The volumes of the Thames at Henley, "as well as those of the Kennet and the Loddon, "have been repeatedly gauged, and the results "obtained lead me to the conclusion that at the time "of the shortest water the quantity passing the point "at which we propose to take our supply is not less "than 55,500,000 cubic feet, or 345,000,000 gallons "daily. This is the minimum of the gaugings, and "taken near the termination of an unusually long "protracted season of drought."

5521. Have you calculated the area and the number of inches that would give you that 345,000,000 gallons?—Each inch of available rainfall would give 100,000,000 gallons per day during the year.

5522. Then you would get not quite $3\frac{1}{2}$ inches?—It would be about $3\frac{1}{2}$ during the driest season.

5523. It has been calculated that you catch 5 inches out of a rainfall of 25 or 26 inches in the year?—13 inches was Mr. Blackwell's calculation. One half is lost by evaporation and absorption, and 13 inches passes down into the Thames; but if the flood water, as I propose, were saved by raising the levels of the different weirs, and canalizing the Thames in a more perfect manner than it is now, much more than 13 inches might be obtained, because during floods the water passes over and inundates the country, and a great deal of water is lost both by evaporation and by absorption.

5524. You mean that there would be no difficulty in storing, by means of reservoirs or otherwise, the flood waters in the upper districts?—In the Thames reservoir itself I should propose to store the whole of the flood water of the Thames. There are 2,000 acres of available area in the bed of Thames itself for storage, and what I propose is to canalize in a more perfect manner than it is at present the Thames, both

for the supply of water and for improving the navigation.

5525. Between each lock you would constitute the river a reservoir?—Yes, by means of embankments.

5526. Could that be done without inconvenience by flooding?—Yes, it would prevent floods. It would remove the inundations entirely. We should have to embank the Thames. In many places there is high ground on one side, but where it was required we could embank the Thames, and we could in that way get a storage for 5,000,000,000 gallons, equal to 25 days supply of London, taking 10 feet as the average depth over the 2,000 acres.

5527. Do you mean that the area of the Thames is 2,000 acres?—Yes, the area of the bed of the Thames alone above Henley is 2,000 acres.

5528. Would there be any difficulty in storing the storm water at a very much lower point than Henley for the purpose of feeding the Thames?—I do not know any place so convenient. Of course you might canalize it in the same way all the way down.

5529. But with regard to the several locks below Maidenhead, if those locks were raised a given height, you would store just in proportion to that height?—You might do so all the way down to the sea, but the object in taking the water at Henley is to take it from a pond on a level 105 feet above low water of the Thames, and obtain by gravitation a supply of 200,000,000 gallons a day without pumping.

5530. It would be possible, would it not, to adopt your view of intercepting the flood water above Henley for the purpose of giving you gravitating power to supply the higher parts of the metropolis, and at the same time to store the flood water at a lower point, and bringing it down to the metropolis for the purpose of supplying those parts which are not of the same height?—I have sent in a small section to your Royal Commission, on which (if you will be so good as to refer to it,) you will see the aqueduct and the levels of various places in London. The level that we propose for the aqueduct is the same as the New River Head in London, or about 100 feet above low water of the Thames at London Bridge.

5531. With regard to your high level, of course it gives you a greater head than if you were to take the water at a lower point?—It does.

5532. Will you describe the course of your aqueduct, and how you propose to carry it from Henley to the metropolis; would it be in open cutting?—It would be an aqupduct or canal 36 miles in length, but for the last five miles near London it would be covered; the width of the aqueduct would be 40 feet, and the depth 12 feet, having a fall of three feet or one inch per mile, which would be sufficient to deliver 200,000,000 gallons daily at the level of the Paddington Canal or the New River Head, 105 feet above low water of the Thames at London Bridge.

5533. In your judgment will that fall be sufficient?—Quite so.

5534. And that canal 40 feet by 12 with a fall of one inch per mile would give you a discharging power equal to 200,000,000 gallons?—Yes, at the level of the New River Head on the Paddington Canal.

5535. Is the open cutting of the same size all the way through, or does it increase in size as you approach the metropolis?—To bring the whole 200,000,000 gallons it would require to be the same size throughout, but within five miles of the metropolis I should propose to cover and divide it.

5536. Do you take in any other water in the course of your aqueduct than that which you catch near Henley?—In this scheme it was not proposed to take in any other, but the Brent might be taken in and the Colne from Watford.

5537. Then you would have it the same size throughout?—Yes, the estimate is for the same size throughout.

5538. Do you propose to line it?—It is proposed to be a regular aqueduct puddled the same as any canal, but not for the purpose of navigation.

5539. Would you line the sides with rubble or stone, or concrete?—It would be lined throughout, we should puddle the bottom and puddle the sides and line them when required.

5540. I presume that the fall of one inch would not interfere with you at all, with regard to the sides of your canal?—No, not all. The object is to deliver it as slowly as possible for the purpose of having the river water purified by allowing the materials in suspension to settle. The velocity would be under three-quarters of a mile an hour, so that the water would take about 48 hours to come into London from Henley Pond.

5541. Was your canal to proceed from near Henley to Hampstead?—Yes, you will see the site of the reservoir on the section.

5542. Is it on Hampstead Heath?—No, the main reservoir brings it in at the level of the Paddington Canal, where the first reservoir is shown on the plan.

5543. What height above high water will you be at the reservoir near to Hampstead?—105 feet above low water at London Bridge.

5544. You would require, would you not, to pump the whole of your water?—No, about five-eighths of London would be supplied from that level by gravitation; it is the same level as the New River Head.

5545. Would 88 feet head five miles off be sufficient to resist the friction and supply at the proper height?—It would be just the same as the New River is now. Whatever the New River will supply now, this would supply to the East End of London, and it would also supply Surrey. We proposed to make a reservoir on the Surrey side.

5546. From the reservoir at Hampstead, I see on your section, there is a line accross the Thames to Surrey?—Yes.

5547. Where is that reservoir to be?—At Clapham, supplied from the high level after having been pumped up to the Hampstead reservoir.

5548. How was it to be conveyed from Hampstead to Clapham?—Through pipes.

5549. Was it by gravitation?—By gravitation from the reservoir at Hampstead.

5550. Would your 105 feet be sufficient for that?—No. You will observe there are two reservoirs, the one close to the Paddington Canal, where it was proposed the pumping station should be situated in connexion with the Paddington Canal where coal might be obtained. The water at a level of 105 feet would supply all the low part of London, and the water for the supply of the higher part of London would be pumped from the reservoir at the Paddington Canal up to Hampstead Hill.

5551. Would that give you a sufficient head to bring it to Clapham?—Yes, to supply the whole of London. The object was to have the constant pressure and high service for the whole of London. The reservoirs since constructed by the various companies would, I believe, be sufficient for high service.

5552. What is the size of your reservoir near Hampstead?—It is not large, because the whole aqueduct would form a reservoir 36 miles long, and having a sectional area of 480 feet, and in addition there would be the reservoirs of Henley, and all the levels of the Thames above and beyond Oxford, in all upwards of 2,000 acres.

5553. Are there any other advantages than that of the head in taking the water so high up the river as Henley; why not allow it to flow down the river and take it at a lower point provided the impurities are intercepted, and the river is preserved from that pollution from which it now suffers?—There are other advantages in addition to the head of 105 feet which is obtained by taking the water from Henley. There is the purity of the water at Henley and the comparative excellence in quality.

5554. This plan of yours involves pumping; have you calculated the additional cost supposing you took the supply of water at a lower point in the river and saved the construction of this aqueduct?—The additional cost of pumping, including works, would be

J. R. McClean, Esq.

27 June 1867.

75,000*l.* per annum, but the same water could not be obtained either as regards purity or softness.

5555. Have you any other reason than that of the height of taking the supply at so high a point as Henley?—We found that the best point for the reasons stated in Mr. Blackwell's report, viz.:

"I will now speak of the *quality* of the water at the point where it is proposed to take it. It is well known how much this depends on the nature of the soil over or through which it flows. Thus some rivers which drain a country principally formed of magnesian limestone acquire a medicinal property, which renders them quite undesirable for a water supply. Others, again, flowing through a new red sandstone district, acquire a red tint which no filtration will deprive them of."

"Turning, then, to the soils drained by the rivers Kennet, Lodden, and Thames above Henley, I find them of the nature best suited for furnishing a pure and wholesome water. Indeed, looking at the vast area of chalk and porous sand and gravel in these districts, it is evident that the greater portion of the water is in reality *filtered*; that the rain falling over at least 800,000 acres passes through the porous subsoil of the uplands and comes filtering out in the valleys of the Isis, Kennet, and Loddon. The river Kennet, on which I have long been professionally engaged, is characterized by this peculiarity. Its total drainage is about 460 square miles, of which at least 400 are of this absorbent character, and the slopes of the land are generally so flat as to allow this filtering and absorbent character to take the fullest effect, as indicated by the unfrequency of floods, the regularity of the summer flow, and general purity and clearness of its waters."

"With regard to the chemical quality of the water of this district, analysis shows that it contains nothing prejudicial to health, but only the same inconvenience popularly called 'hardness,' which is peculiar to the water of that wide geological area occupying the south-east of England, and caused by the solution of the carbonates and sulphates of lime, which preponderate in the earth of that district. The analysis of the water of the Thames *above* the confluence of the Kennet shows the quantity of saline and earthy matter to be about $20\frac{3}{4}$ grains per gallon, and the quantity in the river Kennet to be only $15\frac{1}{2}$ grains per gallon, the relative hardness of the two samples by Dr. Clark's standard being in the Thames 18°, and in the Kennet 13°."

"Another influence on which the quality of river water depends is the number of towns and the proportion of the population to the area of its drainage. In this point of view the water of the Thames at Henley may be regarded as singularly pure. The average number of acres to each person, taking the whole of England, Wales, and Scotland united, is about $2\frac{8}{10}$, whilst the proportion in the area supplying the Thames above Henley and tributaries is as high as $4\frac{3}{10}$ acres to each person, showing the population to be thinner in this district in proportion to extent of country than in Yorkshire, Devonshire, or Cornwall, thinner, in fact, than over any equal area in any part of England."

"This fact will be better understood by recollecting that almost the entire drainage of the Loddon, the greater portion of the Kennet, and much of the Isis and Thames is derived from pasture districts, embracing the wide ranges of the Marlborough and Avebury Downs, the Vale of White Horse, the eastward slopes of the Cotswold Hills, the Ilesly Downs, Bagshot Heath, &c."

"Having glanced at the natural quality of the water dependent upon the soil, and the ratio which exists between population and area, there remains only to look at the nature of the manufactures and works established on the streams, for in proportion as these are of a delcterious character, so will the purity of the water be further affected. There are no manufacturing towns in the district. The mills above Henley are almost entirely used as corn mills, there being very few paper manufactures, whilst below Henley-on-Thames and tributary streams these become numerous and extensive. On the Wycombe stream, for instance, from that town to the junction with the Thames at Bone-end there are not fewer than 11 paper mills."

We had samples of water taken recently above and below the junction of the river with the Kennet, and we found the water below it better and more abundant.

5556. Can you give us an analysis of the water taken at that point?—Yes, I will hand in the analysis of the water taken both above and below the junction with the rivers Kennet and Lodden.

The witness delivered in the following paper:—

7, Quality Court,
Chancery Lane, June 1867.

SIR,

I BEG leave to report to you the results of my analysis of two specimens of water taken at your desire by my assistant on 28th May 1867, and marked as follows:—

"No. 1, taken from the Thames about 300 yards above Caversham Bridge, May 28th, 1867, 11.15 a.m. Temp. 57° F."

"No. 2, taken from the Thames below Boulney Court, Wargrave Marsh, May 28th, 1867, 3.15 p.m. Temp. 58° F."

Both specimens of water when viewed in bulk had a slight yellow colour, No. 1 being somewhat deeper in colour than No. 2. They are free from any unpleasant taste or odour. They also both exhibited a small amount of suspended matter, most likely occasioned by the agitation of the river by the wind, the day upon which they were taken being rather windy, but this suspended matter readily settled out of both on their being allowed to stand for a few hours.

The following is a Table of the results of my analysis in a gallon of each:—

	No. 1. Grains.	No. 2 Grains.
Total solid contents	24·16	23·20
Consisting of—		
Mineral matter	22·32	21·60
Volatilized matter by carbonization	1·84	1·60
Oxidizable organic matter contained in the above volatilized matter by carbonization	0·95	0·66
Degrees of hardness before boiling	15·2	15·0
Do. do. after do.	4·6	4·4

The mineral matter was found to consist as follows:—

	No. 1. Grains.	No 2. Grains.
Silica	0·88	0·80
Peroxide of iron	0·56	0·64
Lime, principally as carbonate	8·64	9·09
Magnesia	0·63	0·63
Potash	0·68	0·80
Soda	1·61	1·59
Ammonia	0·016	0·009
Nitric Acid	0·896	0·752
Sulphuric acid	1·66	1·22
Chlorine	0·15	0·10
Carbonic acid and loss	6·598	5·969

On comparing the above results, it will be observed that in many respects these waters are very much alike, but in all the most material points, namely, the oxidizable organic matter, the ammonia, the nitric acid, and the sulphuric acid, No. 2 water, is the best as containing less of these substances. The colour noticed when these waters are viewed in bulk would no doubt be removed by a proper filtration.

I remain your obedient servant,
(Signed) DUGALD CAMPBELL.

J. R. M'Clean, Esq., 23, Great George Street, Westminster.

5557. That analysis shows that the water is of a hardness not exceeding 15 degrees?—Yes, previous to boiling, but it is capable of being boiled down to 4·4. In looking over the report of the Government

Commission in the year 1851 I find that this water compares well with any other waters that had been sent in. (*The witness delivered in the report.*)

5558. (*Mr. Harrison.*) That was at the period when the companies took a great deal of their water lower down the river than they do now?—Yes, they took it at Vauxhall and some at London Bridge. It was before the water was taken above the tidal influence of the river.

5559. (*Chairman.*) What was to be the cost of this work?—The estimate was 1,500,000*l.* I have not gone into it recently, but of course during 20 years engineering has made great progress, and there may be great changes in the estimate.

5560. You would have to add, would you not, for the increased cost of labour and materials something like 30 per cent. between 1851 and this time?—I have not found much change in prices since that period, at least in the cost of executing the whole of a work. The price may have increased as regards a portion of it, but, taking it as a whole, work is now as cheaply done as it was 20 years ago. The application of machinery is so great and the improvements that have been effected, even in excavating, make work about the same cost now as then.

5561. But the price of labour has considerably increased?—Yes, but you do not require so much manual labour; machinery supplies its place, and keeps down the price of the work.

5562. Then concrete would be very much more expensive now would it not?—Lime is not dearer now than it was then, and there is gravel everywhere throughout the proposed work.

5563. Lime is dearer now than it was in 1851, is it not?—I think not.

5564. Is the 1,500,000*l.* of which you have spoken the cost of the aqueduct?—Yes, it includes the cost of the aqueduct, the reservoirs, and the raising of the Thames at Henley, but not the improving the river above Henley.

5565. When you speak of raising the Thames you probably mean raising the river?—Yes, raising the level of the river by means of embankments and locks.

5566. And does it include the cost of carrying the water from Hampstead Heath to the Surrey side of the river at Clapham?—Yes, it does.

5567. What was the additional cost of the loop across to Clapham?—It is included in the estimate.

5568. Referring to the cost, do you mean that the sum of 1,500,000*l.* is the structural cost, or does it include the purchase of land, easement, and severance?—It includes the purchase of land. The valuation at that time was made by Mr. Henry Hunt, and it includes machinery, bridges, and everything to bring the water into London and up to Hampstead.

5569. How did you propose to carry out your scheme in 1851?—By means of a Commission.

5570. (*Col. Harness.*) Did your estimate include the pumping for raising the water to the reservoir at Hampstead?—No, pumping above the level of 105 feet above the Thames would be an annual cost.

5571. (*Chairman.*) I understand that the structural work does not include even machinery?—It does. The estimate of 1,500,000*l.* is for the cost of aqueduct for its whole length, including reservoirs, and land, and compensation, and including iron mains and pumping engines and all contingencies.

5572. (*Col. Harness.*) Therefore, that would not put any water into the higher Hampstead reservoir?—No. It does not include pumping.

5573. (*Chairman.*) Can you shortly state the scheme that you suggested in 1850, whether it was to be carried out by means of a joint stock company or a commission and municipal authority?—At that time we proposed to have it carried out by a commission, but the termination of our work was the passing of the Waterworks Act of 1852 (*handing the same to the Commission*), which has settled the question up to the present time. The water companies at that time agreed to take the water above Teddington Lock and the question was practically settled.

5574. Will you shortly describe your own scheme?—I have nothing more to add, except as regards the areas of the catchment basins that have been suggested to the public. The Thames above Henley is 2,500 square miles, and will require only 2 inches of effective rainfall to supply 200,000,000 gallons daily. The area of the sources of the Severn are only 204 square miles, and will require 25 inches of effective rainfall, and from the Cumberland lakes 177 square miles, 28 inches of effective rainfall will be required for the same quantity. It is proposed that the surplus water not required for domestic, trade, or ornamental purposes, should flow daily through the Paddington canal and the various sewers which pass under it into the Thames; so that practically an arm of the Thames, 105 feet above low water, would be continually cleansing the metropolis.

5575. Has anything occurred in the government of the metropolis since that period to cause you to alter your scheme with reference to the authorities to carry it out?—Yes, the constitution of the Metropolitan Board gives facilities now for carrying it out in a better way than proposed at that time.

5576. Are you of opinion that the supply of water should be in the hands of a municipal body as a principle?—The supply of water I think ought to be in the hands of a municipal body, but the distribution of the water to the houses, the collection and all the details ought, I think, to lie in the hands of a water company.

5577. Do I correctly gather from your answer that you would constitute the municipal authority the wholesale dealer in water, and that they should contract with parties to distribute that water from a given point?—Not exactly so. The mode that I propose is for the Metropolitan Board to make the aqueduct and the Thames Conservancy to execute the works, to improve the navigation, and to store the water in ponds.

5578. That is to say, the works on the Thames?—Yes, the works on the Thames simply. That the Metropolitan Board should make the aqueduct which should afford the means of supplying London with fountains, watering the streets, in fact every purpose of that kind, or for giving it to the dwellings of the poor unstinted, and that arrangements should be made with the present water companies who have had great experience in the distrbution, so that they should have the water at a level of 105 feet above the Thames to distribute. That would save a great deal of pumping and their present machinery by merely being removed to that point would come in for the high service of London, so that nothing would be lost.

5579. (*Col. Harness.*) Would you have two sets of distribution pipes over the same district, partly in the hands of the company and partly in the hands of the Metropolitan Board?—Yes, you would have additional pipes, you would not disturb the present pipes that belong to the water companies, but you would have additional pipes for watering the streets, the same as in Paris; they have two supplies there, one is from the Seine and the other from the Canal de l'Ourcq for the streets, for all municipal purposes and for fires, which do not interfere with the house supply. In Paris at the present time every street is constantly being watered. The supply is so abundant that to waste water is impossible.

5580. (*Chairman.*) Would not it be a serious question to duplicate the network of pipes in the metropolis?—I should think not if it is only for public purposes for hydrants, for fountains, and for fire.

5581. Would you propose to have a second pipe in every street in the metropolis or in the principal streets?—I have not gone into the details but it has been very well carried out in Paris where they have two supplies without any difficulty. There the pipes are carried in subways and it is quite immaterial whether there are one or five sets of pipes.

5582. (*Col. Harness.*) Therefore their repair does

J. R. McClean, Esq.

27 June 1867.

not necessitate the removal of the surface of the street?—It does not.

5583. (*Chairman.*) Do you see any practical difficulty in the municipal authority carrying out those large works, bringing the supply of water from a distance, constructing the aqueduct and reservoirs, and then letting it to parties for the purpose of distributing the water amongst the inhabitants?—I see no difficulty.

5584. What is your special reason for stopping the action of the municipal authorities at the end of your aqueduct?—Merely on account of the experience of the present companies. It might then be under municipal regulation, but my object was to interfere as little as possible with the present piping and works of the various companies, but I see no reason why they ought not to be under municipal management.

5585. Supposing arrangements were to be made with the several companies would it not produce more harmony of control over the general distribution of the water if the whole thing were under the management of one body?—If there were no difficulties in making the arrangements I believe it would be so.

5586. Then it was to save the present several companies their pecuniary interests that you suggested this special arrangement?—It was, and because there was no machinery at that time to carry out any other system.

5587. Have you turned your attention to the question of the constant as compared with the intermittent supply?—I have.

5588. What is your opinion upon that question?—I have adopted it upon a very large scale in Staffordshire, and the whole of the district between Burton and Dudley, and even beyond as far as Brierly Hill, a length of nearly 40 miles, is under high pressure and constant service.

5589. Do you mean the several towns in what is called the Black Country?—Yes, the district comprised in the supply is marked in this map (*handing in a map to the Commission*). We are now proposing to carry it further to Birmingham and to make it all one district.

5590. Are you the engineer to those several towns?—In South Staffordshire for the towns shown on the map I am, and I have been from the first.

5591. Do you take your supply from one source or from several sources?—From one source. At the present time we take it entirely from the new red sandstone of the Permean measures.

5592. Do you obtain a sufficient supply for the several towns for which you are engineer?—We have not been obliged to resort to any surface water. The company are pumping now 4,000,000 gallons a day and distributing it over the district which you see on the map; they have facilities for collecting an almost unlimited quantity of water running down from the high land of Cannock Chase if it should become necessary to resort to that source hereafter.

5593. Is 4,000,000 gallons per diem equal to supply all those towns in the Black Country?—At the present time it is, but we have the means of giving 10,000,000 gallons more.

5594. What quantity of water per head do you allow per diem?—We allow an unlimited supply.

5595. What is the consumption per head for domestic and manufacturing purposes?—I do not know the number of persons supplied.

5596. Have you formed any distinct idea as to the proper quantity for the metropolis, including manufacturing purposes?—I think it ought to be unlimited. There ought to be no restriction on the supply.

5597. What quantity per head would, in your judgment, be an abundant supply for all purposes, domestic, sanitary, and manufacturing?—There is great difference of opinion. In Staffordshire, where the supply is unlimited, and where there are so many large works, and where the water is continually laid on, the supply is only 11 gallons per head for the entire population, but I do not know how many use the water.

5598. Are we to understand that all the towns in the district coloured on this map which you have handed in are supplied on the constant system?—They are.

5599. How long has it been in operation?—About seven years.

5600. Were you the engineer prior to the adoption of that principle?—I was the engineer who suggested the whole scheme. Those towns had no supply of water except from the canal.

5601. Speaking from memory, can you state whether the application of the constant system has led to a waste of water or to economy?—We never had any system except the constant system; the works were constructed for the constant supply and high service.

5602. Therefore you have no means of contrasting the two systems?—No, except that we know what the cost of the water is, and we know what the water rents are.

5603. Speaking generally, are you of opinion that the constant supply system is the proper one?—I have no doubt of it.

5604. Can you state your reasons for that preference?—They are partly sanitary. Since that system was adopted the health of the people has improved very much in that district. There was not a single case of cholera during the recent outbreak in the district supplied from Lichfield, where we pump the water out of the sandstone.

5605. How did the poor people store their water prior to this system?—In all kinds of vessels. The women and children were constantly employed in the Black district in getting water and wrangling about the wells.

5606. The receptacles, I presume, were filthy in some cases?—Yes; at the present time the supply costs 1*d.* per ton; that is the charge made.

5607. How many gallons would that be?—224 gallons; it is cheaper now for them to take water into the houses by means of the waterworks company than to take it from the door if it were placed there gratuitously.

5608. How are the arrangements made for the supply of the houses of the poor; is it by means of standcocks?—No; a tap in each house is what I have tried to get everywhere.

5609. Have you found any difficulty in maintaining those taps?—None whatever.

5610. Have they been stolen or destroyed?—No, with few exceptions.

5611. Have you any special powers in your Act to superintend and inspect, or to punish parties for interfering with the taps?—We have unusually large powers of inspection, but we have seldom had to exercise them.

5612. Have you the means of detecting any serious waste in any part of the district?—We should detect it immediately.

5613. I mean on the works; could you detect it by any gauge constantly in action?—Yes. Whenever we suspect any consumer or any company of taking more water than they pay for, we put a gauge on the pipe going into their works, and ascertain the exact consumption.

5614. Are the large consumers supplied by means of a meter?—Yes, the very large ones are.

5615. At what rate per 1,000 gallons did you charge them?—The average is 5*d.* per 1,000 gallons, and the charge for the whole district, including everything, is 4½*d.*

5616. Then, of course, in preparing your mains and distributing your pipes, you gave to them a sufficient capacity to resist the pressure, and adapted them to this system which you have adopted, namely, that of constant supply?—Yes, the works were commenced on the high pressure system.

5617. Have you found any difficulty from breakage in any district?—None.

5618. Could that system be applied to the pipes which you are aware that we have in the metropolis?

—I have not sufficient knowledge of the pipes to know.

5619. In the case of pipes which have been long down, and are partly oxydised, it would be necessary to renew them before you could apply the constant pressure, would it not?—Not in London; we have a high pressure you may say now, but an interrupted one. The houses here 40 feet high have water to the tops of the houses, but it is only admitted for about two hours a day, so that the pipes would not require any additional strength.

5620. If you have the full strain on, and a pipe will resist that pressure for two hours, would it not resist the same pressure for 24 hours?—Yes, certainly.

5621. As far as the application of the constant system to the metropolis was concerned, it would simply have reference to the internal arrangement of the pipes for closets and other purposes?—Yes, it would, and getting rid of cisterns.

5622. Have you any special tap that you use in your district?—Nothing but the ordinary screw tap.

5623. And is that found sufficient?—Yes.

5624. How do you arrange in cases where the better houses in the district have waterclosets?—They are put on direct, with a small cistern containing merely a few gallons, but there are only a few large cisterns I believe.

5625. Then it is simply a catch basin?—Yes, some little arrangement of that kind.

5626. Immediately that basin is emptied it is refilled by the constant pressure?—It is.

5627. And that cuts off any communication of gases from the closet to the water?—Yes, it does.

5628. And that is a very small affair?—Yes, very small.

5629. Have the poorer classes closets?—The poorer class have not closets in Staffordshire; they generally have privies outside.

5630. And the night-soil is removed?—Yes, but the higher class have closets now; formerly they were not able to procure them on account of the expense and want of water.

5631. With regard to the poor would you deal with them in the same way as you do with the class of persons that you have described, by giving them a watercloset with a small cistern for the immediate use of the closet?—Yes, and so I would give them an unlimited supply.

5632. Have you any cases where there is simply a tap into the main, and by turning the tap the water is turned off from the main?—None into the closets, but into the houses. The water comes direct from the main.

5633. Would it be objectionable in your judgment to have a tap liable to be left running into a closet and wasting the water?—The objection is more imaginary than real, but one would not like to recommend it.

5634. But looking at it as a whole, you see no difficulty in the application of the general principle of a constant supply?—I do not.

5635. Do you think that sanitary regulations would be considerably promoted by the application of the system?—Yes.

5636. And having regard to the purity of the water and the freedom from those contaminating influences resulting from imperfect storage, do you think that the health of the people would be improved?—I believe so, besides the economy is very great. By steam power water is taken to the top of a house 40 feet high for 1*d.* per ton, it is a most economical mode of raising water.

5637. Speaking generally of the Thames watershed, are you of opinion that it is possible to catch a sufficient quantity of water to supply the metropolis now and for many years hence?—Yes, by storing the flood water in the upper reaches of the Thames as I have described I have no doubt that you may obtain more than any quantity that can ever be required.

5638. Then you think it unnecessary that the metropolis should seek for a supply of water from wells or from the lakes, or from any distant point?—I do. In the paper which I have handed in, the report of the former commission analysing the water of London, they go particularly into that point about the wholesomeness of the Thames water, and they say that none of the salts that are in it are at all injurious to health, the only difficulty is about the quantity of soap that is required.

5639. Has your attention been directed to the question of the use of soft water as compared with water of 15 degrees of hardness and its effect upon health?—It has to a certain extent. I am engineer to the Eastbourne waterworks, and when I became their engineer the supply of water was from the chalk. I induced the Duke of Devonshire who is the principal person there to pass through the gault down to the green sandstone in place of taking the water from the chalk. There is an abundant supply from the chalk, but the water from the green sandstone is very much superior to the water from the chalk, and now the town which is a very important and rising one is supplied by constant service.

5640. What is the degree of hardness of that water as compared with the water previously used?—The Eastbourne chalk water is $13\frac{1}{2}^{\circ}$ (Clarke's scale). The Eastbourne green sand water is 8° (Clarke's scale). In Staffordshire the water is from the Permean measures, but we find no difficulty on that score, it is all good water, and is 8° of hardness (Clarke's scale).

5641. In your opinion is water of a moderate degree of hardness better for the health of human beings than soft water?—I believe it is. People are obliged to go to watering places for the purpose of getting salts; but for general purposes it depends on the nature of the hardness, and whether it is temporary hardness, which may be softened by boiling, or hard from constituents which cannot be removed by that process; or sulphate of lime, which renders the water unfit for culinary purposes.

5642. Does that apply to cattle?—Without giving a medical opinion I believe that the more salts there are in a water the better for the human system, excepting some of the objectionable ones which are mentioned in the report containing nitric acid and one or two other salts.

5643. (*Mr. Harrison.*) You stated that out of a rainfall of 26 inches you calculated that 13 inches would be available?—Yes, if required.

5644. We have had evidence before us based upon observation extending over at least 11 years which shows that the actual quantity discharged in the Thames does not average more than one-third of the rainfall, that is to say, eight inches?—Yes, I have no doubt that there is a great difference in different districts.

5645. But taking that which is discharged at Teddington Lock it amounts to one-third of the average rainfall which is about 26 or 27 inches. Supposing that you were to take the water as you propose from Henley, should you not have to make some provision for the remaining portion of the Thames below that point to keep it with a sufficient supply of water in it constantly?—Yes, by storing the water in the reservoirs I have referred to you may have a quantity of water constantly running over the weir below Henley nearly equal to the supply in seasons of drought.

5646. So that by your scheme you would never reduce the quantity say at Windsor below its present minimum volume?—Quite so.

5647. (*Chairman.*) Do you mean that you would never reduce the water level?—I believe there never would be less than 300,000,000 gallons passing over the weir at Henley.

5648. (*Mr. Harrison.*) And that you would obtain by raising the banks of the river at the different locks, in point of fact canalising the river and converting it into a reservoir?—Yes, of an area of 2,000 acres.

5649. (*Col. Harness.*) And a depth of 10 feet?—Yes, and an average depth of 10 feet.

5650. (*Mr. Harrison.*) You mean not only that you would keep the surface level of the water of the Thames below Henley at the same level as it is now,

J. R. McClean, Esq.

27 June 1867.

but that you would actually allow from the reservoirs above Henley the same daily quantity of water to flow as a minimum flow into the river below Henley as does now?—That is so.

5651. Do you think that since the period of your estimate you would not find a large increase in the value of land, particularly at Hampstead where your reservoir would be?—That may be so, I have not gone into that; Primrose Hill was the place for one reservoir.

5652. Excepting the value of the land you are of opinion that things would remain the same?—Yes.

5653. There is one important question which arises out of the system of the South Staffordshire Waterworks which I should like to ask you about. This is almost the first case, is it not, in which the towns in a large district of country have been grouped together under one system of supply?—It is.

5654. The population, excluding Birmingham, included within this district is about 400,000, is it not?—Yes.

5655. Do you think that you are now supplying the whole of that population of 400,000?—No. It requires a considerable time for a waterworks to attain its maximum.

5656. Can you tell what proportion of that 400,000 is supplied?—I cannot.

5657. I ask that question because I see that your present quantity is only 4,000,000 gallons a day which to supply a population of 400,000 would be equal to only 10 gallons per head?—It is more than that at the present time, that is assuming the whole district to be supplied.

5658. At present you derive the whole of your water by a tunnel which you have drifted into the red sandstone?—We do.

5659. And by additional tunnels at different places into this red sandstone of the Permean measures you would expect to get a much larger supply if necessary?—Yes.

5660. Do you think that it would be advisable to adopt the same principle of grouping districts in other parts of the country as you have done in Staffordshire?—I think it would be very desirable where you have a quantity of water suitable and available for household purposes.

5661. Do you think it would be desirable when water companies are seeking powers from Parliament, say for one large town, that they should at the same time be under an obligation to supply any adjoining small towns in the district?—I think it would be very desirable if the small towns agreed to pay for the same.

5662. By combining, as you have done in this case, to a large extent, do you not think that you would be justified in going to a larger outlay than you otherwise would do?—I think so, that would be the most economical way of doing it.

5663. And by enforcing such a rule the general public would in the end be much better supplied than they otherwise would be?—Undoubtedly, and with much purer water.

5664. By your Act of Parliament you take power to supply all those towns?—We do.

5665. And you are at the same time under the obligation to supply them?—We are. Under the General Waterworks Act we are obliged to give a supply when the pipes are in a certain district, or if the householders are willing to pay 10 per cent. on the cost of putting a pipe in a particular street. You will find under the General Act that there is no compulsory clause beyond that.

5666. Are there not a great number of cases in which that General Act really would hardly apply?—There are.

5667. (*Chairman.*) When you say that the householder has to pay 10 per cent. do you mean that 10 per cent. is to be paid by the householders in a street?—The aggregate householders have to pay 10 per cent. upon the cost of the pipe.

5668. (*Mr. Harrison.*) Excepting in cases where you are within a reasonable distance of a town, that provision would be entirely nugatory?—Yes.

5669. And in many cases I daresay you will find that there are large towns and villages which you have not supplied at all?—There are a few. We already supply Burton and a portion of Lichfield, Walsall, Wednesbury, Bloxwich, Brownhills, Pelsall, Rushall, Darlaston, Tipton, Great Bridge, West Bromwich, Oldbury, Smethwick, Handsworth, Dudley, Rowley Regis, Ledgley, Kingswinford, Brierley Hill, The Lye, Halesowen, Streethay, and several other towns in the district. We have not got the pipes to Tamworth yet, but the corporation there have the matter now under their consideration.

5670. Do you know the area of the present district which you supply?—The area is 250 square miles, and the total population is about 400,000, and negotiations are now being carried on between the Birmingham Waterworks Company and the South Staffordshire Waterworks Company to put the whole under one management, and Wolverhampton may eventually be under the same, so that there may be a population of upwards of 1,000,000 supplied from the same source. The water is pumped from Lichfield to the summit, 200 feet high, to reservoirs in the Black District, about 200 feet above the average level of the towns.

5671. (*Mr. Harrison.*) I gather from your views that the principle which you have adopted is a sound one to apply generally when water companies are getting their Acts of Parliament?—Yes, when you get a pure source. My attention was called to that subject some years ago with regard to the supply of Hastings. I advised them to get their water from Eastbourne, as the nearest point where the lower green sandstone occurs, in order that they should take a supply from inexhaustible sources.

5672. Arguing from what you have done yourself at Eastbourne, and what you have done in South Staffordshire, it is obvious that you prefer a soft water to a hard chalk water?—Yes.

5673. Generally, is not the water of the Thames at Henley very much the same in character as the water which you would get at Eastbourne from the chalk springs?—No, the chalk formation occupies less than a quarter of the Thames basin above Henley.

5674. Then at Eastbourne you have thought it desirable to go to a better source of supply?—Yes.

5675. That would lead to the conclusion in your mind that if you had had a choice between a hard or a chalk water, as in this case, and soft water, you would prefer the soft water?—People do prefer it. I myself prefer hard water for drinking if it is free from deleterious salts, but for many other purposes soft water is the best.

5676. You have suggested that the Thames Conservancy are the proper parties to bear the cost of constructing the works of the embankment of the Thames above Henley?—To carry out the works.

5677. How would you remunerate them for the outlay?—A portion of it, of course, would be borne by the metropolis, because it would be for storing water for their supply, and a portion from mortgage of tolls, and from the land irrigated and drained.

5678. Then you would merely put the execution of those works in their hands because they are conservators of the Thames?— Yes, because they are conservators of the Thames now all the way up to Oxford.

5679. But you would have to find, would you not, some public body who would furnish them with the means of doing it?—Yes, the Metropolitan Board. It would not be very expensive, and a great portion of it would be repaid by the landowners. From the acreage which might be irrigated, and from which the floods would be entirely removed; the amounts derived from those two sources would form a very important income.

5680. The Thames Conservancy Board, under the Act which they have obtained, are now going to embank some portion of the Thames, are they not?—I

believe they are; but there are places above Henley which are capable of great improvement, and of affording a very valuable area for storage.

5681. (*Chairman.*) You suggested the Thames Conservancy Board as the proper parties to carry out the works in the river probably because they have exclusive jurisdiction over it?—Yes, they must always have it for navigation purposes.

5682. But the works which are to be carried out for the purpose of storing water, or for facilitating the storing of water, being for the benefit of the general public, should be paid for, should they not, by the public, and not out of the funds of the Thames Conservancy navigation?—Not altogether. They would be carried out for navigation, irrigation, removal of inundations, and drainage, in addition to the supply of water to London.

5683. You have referred to the scheme of the South Staffordshire Waterworks Company as that of grouping several towns together in a supply from one common source, by means of a joint stock company; do you see any difficulty in grouping the large towns in the north, between Leeds and Lancaster, or other parts, giving a representative body a control over the water, and each town in proportion to its population being represented on one central board for the management of the water supply of the several towns?—I have not gone into the question sufficiently to give you an answer. On the face of it I see no objection.

5684. Supposing one gathering ground could be used in common for all, and one aqueduct could be made equal to the supply of all, would it not be consulting economy as well as possessing other advantages to have a joint central board to manage the water supply, each town paying its proportion?—I believe it would.

5685. And that in your judgment would be a better arrangement than towns seeking an independent water supply for themselves from sources that might not be so good as some distant gathering ground, which if united they could obtain their water from?—Quite so. In many cases you might get water locally better than by aggregating the towns in that way, but where you have a good and an unlimited source of supply, I believe it is the best way of supplying a number of towns in England. This supply, which I have referred to, might be taken in Stafford and the Potteries where they are very badly off for water, and I do not know where they are going to get it. You might have any quantity of storing ground at Cannock Chase, which is the backbone of England. Both the subterranean water and the surface water are undoubtedly good, and I think it should be made available for Derby and a great many other places which are badly supplied at the present time, but it requires some time to carry it out; it is the only pure source there is.

5686. Has not the time arrived when the question should be fairly looked at as to preserving the gathering ground for the supply of water to the increasing population of those manufacturing districts?—I think it has, and also for preserving the subterranean supply.

5687. The local supply in many cases is becoming polluted, is it not?—It is. The subterranean supply is a more certain supply than the drainage areas in certain geological formations.

5688. (*Mr. Harrison.*) Have you found any diminution at all in the quantity of supply at any period of the year to your tunnel?—None whatever. We have made repeated experiments extending over 10 years. We have bored holes at different places in the tunnel to facilitate the flow of water from it, and I have put a pipe into those bore-holes, and I find that the water rises up in the pipes to exactly the same height that it did 10 years ago. There is not the thickness of a sheet of paper difference between the level of the water when it is pumped now and the level of the water 10 years ago.

5689. Are you aware that in the case of Liverpool where they take their supply from the red sandstone they lowered the level of the water at the place where they pumped from?—I have heard so. I read the controversy about it many years ago, but that is not the case in Staffordshire. It appears that after it rises to a certain level there is some subterranean overflow to the Trent, but up to this level it always rises to that level; the sources seem to be quite inexhaustible.

5690. What is the population of Birmingham?—About 350,000.

5691. If you were to add Birmingham to the present district which you supply you would get in the whole a population of 800,000?—We expect 1,000,000 at the end of two years.

5692. Taking the consumption at 30 gallons per head, which is now generally taken as the calculation, you would require 24,000,000 gallons per day, or just six times your present quantity?—No. We have now 10,000,000 gallons a day.

5693. Do you think you will have a sufficient supply by additional tunnels collecting the surface water?—Yes, I have no doubt of it, even without storing the flood water.

5694. You think that you could supply 24,000,000 gallons from the Permean formation?—Yes, by driving tunnels. Sinking shafts we find of very little use, the shaft only drains a certain area about the base, but the water does not filter through, it comes through in chasms, and you must drive a heading to cut those fissures.

5695. (*Chairman.*) You drive a shaft into the hill, do you not?—Yes, and cut the different fissures, and then the water comes through those fissures like springs, but you cannot get any supply from mere shafts.

5696. You have not only a shaft driven into the hill, but you have perpendicular openings, have you not?—We first sink a shaft and then drive a heading from it through the sandstone.

5697. And that of course cuts all the fissures?—Yes.

5698. (*Mr. Harrison.*) The tunnel which you have in this case is about four miles long, is it not?—Yes.

5699. (*Col. Harness.*) What guided you in the direction which you gave to that tunnel?—The geological map.

5700. With reference to what did you choose your direction?—To keep as much as possible in the one rock from which we found the best water. The pumping station is at Lichfield, and in the part marked F 5 on the geological map we find the purest and best water. The tunnel has been driven along the road to intercept the water. There is a fall of 800 feet which cuts off the communication between the coal district and the Permean formation, and we find that wherever we drive in F 3, F 2, and F 5 we get good water. In F 6 is bad, both the surface water is bad and the subterranean water is bad.

5701. Therefore you went as much as you could through F 5?—Yes.

5702. (*Chairman.*) How many sources have you?—We have only one channel.

5703. Have you more than one well?—No, only one.

5704. And that is found sufficient?—Yes, with the tunnel.

5705. Then you cut the fissures down to a given point, and you carry the channel along, conveying the water?—Yes. It is now under consideration to carry out the same system and make a tunnel between Lichfield and Birmingham, which will be 12 miles long, and it will cost about 80,000*l.* We shall get a supply from the high ground at Sutton Coldfield and all that district.

5706. What evidence have you now to satisfy you that you can increase your supply of from 400,000 inhabitants to 1,000,000, and give them a more abundant supply than they have at present; what evidence have you that this source will be equal to that?—We have now 10,000,000 gallons per day, and we find that for each mile of tunnel we generally get 1,000,000 gallons.

J. R. McClean, Esq.

27 June 1867.

5707. Have you observed any diminution in the quantity in any part of the year?—None whatever.

5708. Do you find that neither a rainy season nor a drought has any effect upon this storing source?—No, because we are still so far within the capability of our sources.

5709. (*Col. Harness.*) With your present arrangements, an overflow arises when you have not been pumping as much as you can take up?—Yes, it does.

5710. (*Mr. Prestwich.*) You state that the length of tunnel at present existing at Lichfield is four miles; do you find that it has had any effect upon the delivery of the streams in the district?—None that we have observed. The brook which formerly was used by the company, but which is now abandoned on account of the great subterranean supply, delivered 1,000,000 gallons daily, and we have found no change on account of the tunnelling.

5711. What depth is the tunnel?—It varies from 20 feet below the ground to 150 feet, all in the sandstone.

5712. Then, in the same way, you might, by a tunnel of that description, intercept the water in any district where the rocks are fissured and which abound in springs; for example, supposing there is a large flow from the chalk above Henley and Pangbourne into the Thames, do not you consider that by an intercepting tunnel of that description you would intercept the springs before they reach the Thames, and secure a supply of spring water of perfectly pure quality?—I do, and I am also of opinion that if a tunnel were driven towards Guildford, into the green sandstone, a very large quantity would be obtained; whether it would be sufficient for London it is a difficult question to answer, but a very large quantity of pure water might be obtained from the green sandstone.

5713. (*Chairman.*) What is the size of your drift?—It is 4 feet 6 by 3 feet 6.

5714. How is it sustained?—It is all in rock.

5715. (*Mr. Harrison.*) Did you make any experiments with regard to the delivery of the springs into the Thames from the chalk above Henley and Goring?—I did not myself, but Mr. Blackwell refers to it in his report.

5716. For how long a period were the gaugings of the river continued at Henley?—For many years in the Kennet.

5717. And what did you find to be the maximum flow at Henley?—The minimum was taken, not the maximum.

5718. What did you find it at Henley?—345,000,000 gallons, but that would be very much increased by the embankment preventing the water going out upon the lands and inundating them, where a great deal is lost both by evaporation and by leakage.

5719. That would put a stop altogether to the flooding of the meadows?—Entirely; it would irrigate them, not flood them.

5720. But at present that is a source of impurity to the river?—Yes, a very great source.

5721. And is it likely to become more so as the system of disposing of the sewage of towns is brought into operation?—Yes; but at Henley we got rid of nearly the whole of the sewage of the population on the Thames which could injure it. The sewage from Reading was intercepted, and the only towns of any importance above were Oxford and Abingdon. Those we proposed to get rid of in the same way by forming embankments and having side cuts, and having separate drainage for those towns, so as to render the Thames as pure as possible.

5722. For how long a period would the river, looking at it as a reservoir, suffice for the supply of water to London?—For 24½ days at 200,000,000 gallons a day.

5723. You stated that the soft water from the green sandstone was preferred to the water from the chalk at Eastbourne,—where was the water from the chalk obtained?—From springs.

5724. Not from wells?—No, from springs.

5725. Have you any analysis of that water?—I have.

5726. You are no doubt aware that the waters from chalk springs differ very materially?—Yes, I believe so.

5727. Did I understand you to state that you thought that the water at Eastbourne was similar to that of the Thames?—The chalk formation occupies less than one quarter of the Thames Basin above Henley. We find at Eastbourne that taking the water from the greensand, even within a distance of 200 yards, does not affect the chalk springs in the slightest degree; the galt between the two separates the waters completely, and, although there is a spring within 200 yards of the pumping station, our pumping at a depth of 75 feet does not reduce; the water in the chalk spring has never been reduced.

5728. Are those chalk springs still used?—The chalk springs are used for irrigating the marshes.

5729. (*Chairman.*) Are there any wells near to the stone which you are tapping at Lichfield, and if so, what has been the effect of your arrangement upon those wells?—We have been obliged to deepen the wells to the level of the water in the tunnel.

5730. Have you reduced the water line considerably?—No, we have not reduced it, but the wells were not down to it.

5731. Your pumping at the lower level had a tendency to draw the water from the upper level from whence the wells were supplied?—Yes, it did so until they deepened their wells to the same level as the tunnel.

5732. Then the water line must be lower?—The water line in those wells would, but we got the permanent water level when the tunnel was made, which has never altered since.

5733. But all sources of supply short of the level at which you are taking the water have failed?—They did until they sunk their wells deeper. We dried every well in the town of Lichfield during the construction of the works.

5734. (*Mr. Prestwich.*) Do you think that the local supply of Birmingham and the district around Birmingham is such, or could be rendered such, as to make it unnecessary to go to a distance for a supply?—I do, by extending the tunnel from Lichfield, and without taking any of the water of the river Tame, which now passes through Birmingham.

5735. Therefore, there being a supply near at hand, that would be the most economical supply?—Undoubtedly.

The witness withdrew.

J. Thorpe, Esq.

JONATHAN THORPE, Esq., examined.

5736. (*Chairman.*) You are deputy chairman of the Thames Conservancy Board?—Yes.

5737. The Lord Mayor is the chairman of that board is he not?—Yes.

5738. And you are the acting chairman?—Yes, the Lord Mayor of London is *ex-officio* chairman.

5739. As chairman of that board, of course your attention has been directed to the condition of the river?—Yes.

5740. And also to the source of the supply of water to the metropolis?—Yes.

5741. The several companies, I believe, are taking about 5,000,000 gallons now?—About 50 millions.

5742. They have a statutory right to take double that quantity, have they not?—I think so. They have by agreement with the corporation power to take 20,000,000 gallons each.

5743. The companies have power under the Act of

1852 to take 100,000,000 gallons in all from the river at the point at Hampton where they take it now?—Yes, I am not quite sure whether the quantity is limited by Act of Parliament or by agreement. I think it is by agreement.

5744. Is that an agreement with the Thames Conservancy?—With their predecessors the Corporation of London.

5745. Was that agreement confirmed by the Act of 1852?—I think so.

5746. Have you observed, as chairman of the Thames Conservancy Board, any evil effects from the abstraction of water from the river?—No.

5747. Are you of opinion that the quantity referred to, namely, 100,000,000 gallons, might be taken per diem without injuring the river as a navigable stream?—Yes, from all that I have learned, I think so.

5748. Do you think it would be prudent to go beyond that quantity?—I think if certain alterations were made in the river, and certain works executed, that quantity might be exceeded without injury to the river.

5749. When you say certain works executed, do you mean works for the purpose of storing water?—Yes, for the storage of water.

5750. You mean the storing of that which would otherwise run off in flood?—Yes, which would otherwise pass from the river. I rather wish to make a few remarks with reference to the upper part of the river, the part above Oxford.

5751. Is not that beyond your jurisdiction?—No, we have jurisdiction 46 miles from Oxford to Cricklade, under the Act of last year, and it is upon that part of the river that I wish to make a few remarks. I may say that little or nothing has been done to store the water, or keep up the head of water in that part of the river, and occasionally there are very heavy floods which are very damaging to the landowners on both sides of the river; indeed an extent of land, we will say from 20,000 to 30,000 acres, is yearly impoverished and damaged by the flooding of the upper part of the river, and the landowners of that part are very willing to contribute to the deepening and otherwise improving the channel of the river and embanking the sides where necessary. That land now lets at sums varying from 10*s.* to 15*s.* an acre, and if the land ceased to be liable to those floods the probability is that it would be increased in value to 2*l.* an acre, so that the owners and occupiers are willing to pay a reasonable sum towards the improvement of the channel of the river in order that floods may be prevented. That improvement and deepening could only be carried out by a system of dredging from Oxford upwards, 46 miles. If the river were to be so dredged, and in places widened, you would have as fine a store for water as you could desire. The landlords would be benefited, and instead of the water being occasionally polluted by stagnant water from land drainage, the quality of the water would be improved, and you would have an increased and a more regular supply. The expense might be defrayed by a contribution from the water companies, and by a rate upon the landowners, who have said that they are perfectly willing to pay, and are most anxious to see such works executed as would relieve them, and by an annual contribution from the barge traffic at either end of the district. A sum might be thus obtained which would enable us to improve that part of the river without distressing anybody, I mean a sum moderate in amount.

5752. I understand that your view is, that the 20,000 or 30,000 acres which are now subject to periodical flooding, and let at the low rent of from 10*s.* to 15*s.* an acre, if freed from those floods, would probably be worth 40*s.* per acre?—Yes.

5753. And the landowners are therefore greatly interested in embanking the river and deepening the channel?—Yes.

5754. And if in conjunction with the landowners, the water companies, and the Thames Conservancy Board, supposing they improve the navigation, were to join together, the river might be greatly improved, increased storage might be obtained, and a large area of land redeemed for agricultural purposes, and with very great advantage to the locality, and to the country generally?—Just so.

5755. Have you formed any idea of the cost of that embankment which would be necessary to exclude the flood waters from the adjoining land?—Most likely the dredging and such arrangements as might be deemed necessary over the 46 miles if that were required (it would not be required in all parts) would amount to from 200,000*l.* to 300,000*l.*; but the work could be only executed gradually.

5756. Do you mean that the dredging would cost that, or the dredging and embanking?—The dredging and embanking, but it could only proceed by degrees, and probably a contribution of something like 12,000*l.* a year would enable those who have charge of it to execute the work; it must take time; it cannot be done offhand, and it would not be necessary to do it all at once.

5757. What is the additional height which you propose to give to the bank?—It would be rather to deepen the bed of the river in most places than to heighten the bank, but the heightening of the bank must be dependent entirely on circumstances.

5758. Have you any other point to which you wish to call the attention of the Commission?—No; that is a matter which I had in my mind, and I thought that perhaps the Commissioners would like to have that view. I have been lately over the upper part of the river with our engineer, Mr. Leach.

5759. When you speak of storage do you refer to the additional sectional area of the river created by raising the bank and dredging the bed, or do you refer to any special reservoirs that might be formed on the adjoining land?—To the deepening of the river and also to the reservoirs which might be made by excavation. In many places the river is very serpentine in its movements from point to point. In a distance as short as from this room to Westminister Abbey you will have four or five turns of the river, and at a very moderate expenditure, by excavation—a straight broad new cut might be made, and that would be the most economical way of increasing the capacity of that part of the river.

5760. Under your present amended powers you are enabled, are you not, to compel parties on the banks of the river or the banks of the streams three miles at right angles from the river to intercept all their sewage and other impurities which have up to this time been cast into the river Thames?—Yes.

5761. What steps have you taken for the purpose of carrying out those powers?—We have power to prevent the introduction into the river of offensive or injurious matter, but where parties under the Health of Towns Act or any other Act of Parliament have permission to pass their sewage by a system of drainage into the river there is a certain course of proceeding pointed out in the Act of Parliament. We have to give them notice and we have to give them time to divert, but in cases where persons wilfully and at once throw filth into the river we take proceedings before a magistrate in the neighbourhood, and if he convicts he may fine them 20*l.*, and we have prosecuted in many instances and obtained convictions; indeed we prosecute in all cases where we find parties wilfully passing impurities into the river.

5762. What steps have you as a board taken in pursuance of the powers granted by Parliament for the prevention of pollution?—The Act requires that we should give notice to the corporations and local authorities that before the expiration of 13 months from date of notice they are to prevent the sewage from passing into the river, and we have given the necessary notices in all cases.

5763. How long have you given those notices?—About four months since.

5764. Have the parties a right to appeal for an extension of time from the 12 months?—Yes; we may give them a time not exceeding three years, and

J. Thorpe, Esq.
27 June 1867.

if they want a further extension of time they must go elsewhere, I think to the Board of Trade.

5765. Your discretionary power is limited to extending the time to three years?—Yes, I think it is three years.

5766. Is that three years from the expiration of your first notice of the 12 months?—No, three years from the date of the first notice.

5767. Then that is an extension of two years beyond the first notice?—Yes, I think so.

6768. Have you served notice upon all the local authorities on the river?—Yes, from Oxford downwards.

5769–5773. To the extent of your jurisdiction?—Yes.

5774. Do you know the paper mills above Cookham in Berkshire which are pouring their filth into the Thames?—No; I do not quite know what you mean by filth.

5775. I am speaking of the result of their manufacturing?—They may be passing something into the Thames, but I am not aware that they are passing into it anything which would be considered damaging to the river, and which we ought to prevent. There is some refuse from paper mills which is not objectionable.

5776. Are you not aware that this refuse is so fatal as to destroy fish?—No, we have no report of anything passing into the Thames that would poison fish.

5777–5779. Are we to understand, speaking generally, that the Thames Conservancy Board are acting up to the powers given by Parliament for the purpose of preventing that which would pollute the river from being discharged into it?—Yes, we are using every effort to prevent the introduction into the river of anything which would damage or injure the water. You are aware that we took proceedings against the people of Kingston; we did all we could in that case, and in all cases we do everything that we can to prevent the introduction of impurities.

5780. Have you enquired into the condition of the Wandle and other streams, into which the refuse of paper manufactories has been discharged, and if so, has it come to your knowledge that the discharge of that matter into the river has destroyed all the fish? That has not come to my knowledge. I have seen the Wandle within a few days, and the Wandle certainly is in a very bad state, but we have not had power to interfere as I think we should interfere. Until recently we could not cause the diversion of such sewage as had been accustomed to flow into the streams.

5781. I am not speaking of sewage, because there would be very little difference of opinion as to the discharge of sewage, but I am now speaking as regards the Wandle and the discharge of refuse from paper manufactories and mills into it. You are aware that proceedings have from time to time been taken against the discharge of that matter into the river in consequence of its interfering with the stream as a fishing stream?—I am aware that proceedings have been taken, not only with reference to the Wandle but the Medway and other rivers in England, against the paper makers, and when those cases have been heard evidence has been given by some that the fluid or whatever was passed was most injurous, and other witnesses have stated as their opinion that it was entirely harmless, and I have not heard of any stand being made, or any proceedings being taken, or any decision given which has had the effect of putting a stop to the introduction of this matter.

5782. Are you aware that the testimony of some of our first chemists has been directly in opposition to that given by Dr. Letheby with regard to the effect of discharging the refuse of paper manufactories into rivers?—Yes, but there are different characters of refuse as far as I understand from paper mills. Some time since we had a report that from Lloyd's paper mill on the Lea there was a considerable discharge of that which was stated to be most offensive and prejudicial; we had a sample of that taken, and it was analysed and reported upon, and the report was that it certainly discolored the water of the Lea, but that there was nothing in it which could justify the assertion that it was prejudicial.

5783. (*Col. Harness.*) Whose analysis was that?—Dr. Letheby's.

5784. (*Chairman.*) Setting aside the chemical question for a moment and the contradictory character of the evidence, would not it to you as a man of observation appear very obvious that that water which would destroy the life of fish could not be good for the human system?—Certainly.

5785. Is it not desirable, having regard to the fact that the Thames is the source of supply for domestic purposes to this large metropolis of 3,000,000 of inhabitants, that such refuse should be intercepted and not permitted to be discharged into the river?—Certainly; everything that injures the character and quality of the water should be intercepted.

5786. As conservators of the river and as a responsible corporate body having charge of the river, what steps do you propose to take to prevent the discharge of any of that refuse into the river?—I have told you that in the case of corporations and local authorities, the course is pointed out to us in the Act, and that we have done all that the Act requires. In the case of individuals we prosecute them if in our judgment they pass anything noxious or improper into the river. Those are the steps that we take.

5787. You state with regard to the paper manufactories that that which destroys the life of fish must be injurious to the life of man, and ought therefore to be excluded from the water. You have received an opinion from Dr. Letheby, in which opinion he states that although discolouration is the result of discharging that matter into the river, yet that is not injurious. I ask you how you reconcile the opinion which you have given with that of Dr. Letheby?—I have not stated that that which is injurious to fish is not injurious to man. I say that it is.

5788. What steps do you propose to take to prevent that either affecting the fish or affecting the 3,000,000 of population in the metropolis?—I have told you that the Act of Parliament points out the way of proceeding in the case of local authorities and corporate bodies, and if we are convinced and we feel that we can satisfy any magistrate or any other authority that that which passes into the river at a particular spot is objectionable, we shall take such proceedings as the Act of Parliament points out, either by a summary jurisdiction, or we may, if we please, prosecute the parties for a nuisance.

5789. You state generally that that is the policy of your board, but you have taken the opinion of a gentleman whom you represent to be your adviser on chemical questions, and he has given his opinion that no injurious effects would result from the discharge of refuse from the manufacture of paper?—In those instances which I have described, not in all instances, or with regard to all kinds of discharge.

5790. My question, therefore, is, having received that opinion, do you intend to act upon that opinion and permit parties to discharge their filth into the river as heretofore, or are you about to take another opinion, or what course do you propose to take with regard to those manufacturers?—I cannot tell you.

5791. (*Mr. Harrison.*) Do you doubt the efficiency of your powers to prevent this pollution?—Not at all. I think we have full powers now.

5792. Are you aware that this question has been fully gone into and judgment given upon it in Scotland in the case of those paper makers on the Esk below Penycuick, and that they have obliged the companies to go to considerable expense to avoid the pollution which is complained of?—I have been informed that cases have been heard and decisions given, but I am not intimately acquainted with the cases.

5793. You are perhaps not aware also of what has been stated as a fact, that in consequence of the investigations which have since been made they find that

they can convert that refuse to a profitable account?—I think it is very likely, but I do not know it.

5794. With regard to the question of deepening the river by dredging, that would of course involve the necessity of lowering the sills of all your locks, would it not?—There are but four locks in the upper part of the Thames from Oxford to Lechlade and all the way to Cricklade.

5795. (*Chairman.*) And those are all to pieces, are they not, like the other locks?—They are all in a very poor state.

5796. (*Mr. Harrison.*) Have you no power at present under your Act of rating the riparian proprietors to your funds?—We have not.

5797. Do you think if you could show so good a case as that which you have stated now, you would have much difficulty in getting Parliament to grant you that power?—I think not; the landowners would be very glad themselves to promote any measures which would have the effect of relieving them of floods.

5798. In the Act which you obtained last session the committee refused you those powers, did they not?—I am not aware that they did. I am not aware that the powers were asked for. That Bill was promoted by the Board of Trade, it was not promoted by the Conservators, and I am not aware that the Board of Trade asked for any such powers.

5799. Your funds are not sufficient at present, I presume, to carry out such a work?—No, we have two funds for Conservancy purposes, the one applicable to the river from Staines to the sea, and the other to the upper Thames. The funds raised for one purpose are not applicable to the other; we have to keep separate accounts.

5800. At present you have no funds at your command to enable you to carry out this deepening of the river above Oxford?—No, we have not the funds to enable us to carry out that which I have suggested.

5801. But independently of that, to the extent of an additional 50,000,000 gallons a day, which, by agreement, the water companies have power to take, you see no difficulty whatever as regards the Thames navigation?—None.

5802. (*Chairman.*) Assuming 30,000 acres to be subject to the periodical flooding which you state, if freed from that flooding it would be increased in value something like 25*s.* per acre; this increased value, say of 1*l.* per acre, would give you capitalized 600,000*l.*?—Yes, but suppose we take it in the other way; what rate per annum would they be willing to pay to the board? We could not spend all the money at once.

5803. If, for example, the proprietors could be convinced that the value of 30,000 acres would be increased by 20*s.* per acre if the several owners were prepared to contribute a rate which would in a given number of years pay off the required sum; giving them some moiety of the saving, the whole cost might be defrayed out of the improvement of the land in question, without the Thames Conservancy or the water companies contributing one shilling?—Yes, but we must look at it fairly. Who are likely to be benefited by those works? The landowners only? Certainly not. The landowners, the water companies, and the navigation. Then, I say, let all fairly contribute. If it is ascertained that 30,000 acres is a fair admeasurement, then an annual tax of 2*s.* would give certainly 3,000*l.* a year, and that for as long a time as such contribution might be necessary, and that would be a very handsome contribution. Then the water companies, who would be greatly benefited, must contribute a fair proportion, and the navigation, I think, probably would increase, so that the receipts from that source would be augmented. The course which I have suggested seems to me to be by far the most economical way of improving and increasing the water supply from the Thames.

5804. You have a contract, have you not, with the existing water companies, that on payment of the sum of 5,000*l.* or 6,000*l.* a year, you, in consideration of that payment, enter into a covenant with the companies to do certain things; to intercept sewage, and to purify the river as a source of supply?—We entered into no such agreement.

5805. Under the recent Act, the water companies contribute 5,000*l.* or 6,000*l.* a year?—Yes.

5806. They contribute that 5,000*l.* or 6,000*l.* a year not for the water which they are now taking, in order that you should, as conservators of the Thames, not up to Staines, as before, but beyond Oxford, as now, intercept, or cause to be intercepted, all filth which now finds its way into the river; in point of fact, to protect the purity of the river in consideration of their paying you that sum?—Yes.

5807. Have you any impurities pointed out in that agreement beyond the sewage of the several towns and villages, and, if so, is one element of impurity that of material discharged from the manufacture of paper?—The water companies agree to contribute 5,000*l.* a year, and it is the duty of the conservators to prevent, as I have stated to you, the introduction of sewage into the river in the mode stated in the Act, and it is the duty of the conservators to scavenge the river, that is to say, to withdraw from the surface or body of the water anything likely to affect its quality. That we do daily.

5808. I am now speaking, not of the water as you find it in the Thames, but as to the contract between your body and the several water companies; what are you to give in return for the 5,000*l.* or the 6,000*l.*?—There is no contract; it is under clauses in the Act that they are to contribute so much.

5809. That is in consideration, is it not, of their contribution; you would not get the water companies of London to contribute 5,000*l.* or 6,000*l.* each, except for a certain consideration?—If you look at the Act you will see what it says.

5810. (*Mr. Harrison.*) In addition to what you have stated, you are also to keep it clear of weeds and such things, are you not?—Yes, to keep the channel clear and to prevent the introduction of sewage, and to scavenge the river, or to do any other work which may be rendered necessary.

5811. (*Chairman.*) You are not able to say whether in enumerating the several matters which are to be intercepted from flowing into the river, the refuse from the paper manufactories is one?—Anything that is injurious. Provided anything which passes from a paper mill is injurious, then it would be our duty to stop its introduction into the river, but I think there is some time given for that, that certain notice is required. There is a special provision with regard to paper mills in the Act.

5812. (*Mr. Prestwich.*) Would your suggestion do away with the necessity of reservoirs above Oxford?—It would almost convert the river into a long reservoir, and for a time it would obviate the necessity of making additional reservoirs; indeed, as far as I know, after having thought of it as well as I have been able, I think it would obviate the necessity of forming reservoirs altogether.

5813. It has been suggested to us that the flood water should be stored in reservoirs, and by that means the flow of the river should be regulated, but you would propose to regulate the flow by deepening and embanking the river?—By deepening and widening, by excavation and by additional water space along the river.

5814. And you think that that would be sufficient?—I think so, or, at all events, for a considerable time; and it would render the construction of other very large reservoirs unnecessary.

The witness withdrew.

T. Macneill, Esq.

27 June 1867.

TELFORD MACNEILL, Esq., examined.

5815. (*Chairman.*) You are a civil engineer, are you not?—I am.

5816. Have you turned your attention to the question of an improved water supply to the metropolis?—I have.

5817. Have you some general scheme by which you propose to take water from Bagshot Heath and the adjoining ground?—Yes, that is so.

5818. Will you describe to the Commission the general features of your plan?—The Bagshot Heath district, which is coloured yellow on the map before the Commission, is a sandy district, where there is very little water at present. It was at one time proposed to bring water, even the small quantity which is in that district, to London, and the whole of the evidence which was given then showed that the water was very good, and that the sands had great power of purifying the water. It occurred to me that as scarcity was the only drawback to that supply, and the water of the Thames flowed so near to it, it would be quite easy to bring the Thames on to that district.

5819. When you speak of purification by means of sand, do you mean that it acted as a filter in abstracting that which was held in mechanical suspension?—Yes, and a great deal more.

5820. How does it deal with that which is held in solution?—It is a process of natural filtration which is not merely sifting the water—it is irrigation and oxydation, with several other things which takes place with the water when it is spread over a large district and allowed to get at the air and at the roots of plants.

5821. That applies to all rain water, but you are now speaking of a filtering bed, that filtering bed being the sand; and that, you say, has a tendency to purify the water?—This is not altogether a bed of sand, there is sand underneath, but it is covered with a bed of peat and decayed heather, which acts as charcoal to a very great extent in purifying the water.

5822. How do you call decomposed vegetable matter, charcoal?—I am no chemist myself, but in the pamphlet which I have sent in to the Commission I have taken the liberty of making some quotations from two eminent chemists, Dr. Angus Smith and Professor Clark. The former, in speaking of this, says, "It is an old remark that humus acts as a char-
" coal filter, although its action here, except as a
" strainer, is difficult to understand, the soil does seem
" to be formed of a mixed charcoal and sand filter,
" which does its work very effectively all over the
" district," and the result of what they say is this, and without exception all chemists who have examined that district, as far as I can gather from them, state that it has very great power of purifying waters, no matter what amount of impurities they may contain.

5823. Do you mean the peat or the sand?—I mean both together, and besides that the filter is of such enormous size that 12 months water remains in the sand, so that it is actually undergoing this process for 12 months.

5824. When you speak of purification do you apply that term to rain water which falls upon the earth, because that is pure in itself?—No. I apply that term altogether to water which is conduced to the Bagshot Sands which I propose to conduct by this process. I have been speaking to Dr. Frankland about this subject from the first time that I had started this proposition, and he offered to investigate it chemically, but unfortunately I have not been able to put him in a position to do it as yet.

5825. Will you proceed to describe your scheme as an engineering scheme?—I propose to give a supply of 200,000,000 gallons daily in the following way. At Teddington weir, where the Thames flows over, I propose to intercept the water and bring it back, as is shown upon the plan before the Commission, in an open cut to near Weybridge, which is 8 miles, where it meets the Basingstoke canal.

5826. Do you propose to take it back simply for the purpose of filtration?—Simply for the purpose of thorough purification and for storing.

5827. Do you go back by gravitation?—Yes, the water gravitates in the open channels, but it is artificially raised into them.

5828. What is the height at Teddington as compared with the site coloured yellow on the plan?—The water at Teddington is 14 feet above Ordnance datum.

5829. I understand you to say that you return the water from Teddington back to the Bagshot Sands for the purpose of filtration, and to enable you to do so you must have four lifts?—Yes, there must be four lifts. The height of the Bagshot Sands varies from 380 feet to 200 feet.

5830. Do you gain any other advantage than simply that of filtration by returning the water from Teddington to Bagshot?—I think so. The water is not only filtered, but it is turned into what may be called spring water, and it never sees daylight from the time it is poured over the sand till it is delivered into London, and the sands will contain 12 months supply.

5831–2. At what depth in the sand do you tap that storing power?—The conduits shown by the red lines on the outside of the yellow district are sunk 30 feet below the surface, and that is about 10 feet below the natural saturated line. The centre conduit will average about 130 feet in depth. I have brought with me a model by which my plan will be much more easily explained. The Thames water is to be brought up by the Basingstoke Canal which passes through the Bagshot Sands; it arrives there at a 200-feet level, and it is sent round in a distributing conduit in this way (*describing the same upon the model*) in order to distribute it into the sands.

5833. This I understand is your channel out of which the water flows into the sands?—Yes.

5834. Is it open cutting?—Yes.

5835. It is an open cutting of course put in with puddling?—There need be very little puddling, if any, the object being to allow the district to absorb the water.

5836. And the water running or standing in this channel will sink rapidly into the sands?—Yes; there are branches from this channel which irrigate the district.

5837. What would be the absorbing power of the sand?—That I have a most excellent proof of. There are natural holes in this district which fill up with water when there is heavy rain, as was the case last winter, but before it had time to disappear the frost came upon it and froze the surface. I went there a few days after that and all the water had disappeared; a skim of ice remained upon the top, but all the water had gone, and that gave me a calculation of the quantity of water that would disappear in a certain number of days, and that was at least equal to an inch in depth over the whole area, which is nearly 14,000 acres; that is a proof of the absorbing power of the sand.

5838. When you say that the absorbing power is equal to an inch over an area of 14,000 acres, does that apply to the whole ridge?—Yes.

5839. How many gallons is that?—That would be equal to 400,000,000 gallons a day. I should mention that that was in an unfavourable place where there was a little more clay and turf carried down from the slopes than was met with in other places.

5840. What depth are those holes on the model?—Not more than three feet.

5841. But are there not points at which the water is discharging from those hills?—Yes, several places.

5842. The capacity of that absorbing power being exhausted the water must naturally flow out in all directions?—The water would flow out in all directions if it is supplied with water. There are small springs, but there is very little visible water indeed in this system of hills.

5843. And you propose to go 30 feet lower?—Yes.

5844. One system is to bring the water and to discharge it into this sand which has that absorbing power?—Yes.

5845. Another is to tap the sands at a level of 30 feet below the surface in order to carry the water back to the metropolis?—Yes.

5846. What does that 30 feet below the surface mean?—It means the outside conduit (*pointing out the same upon the model*).

5847. What depth would that 30 feet be from the ridge—the backbone of this model?—More than 200 feet, but there are other distributing conduits and catchments besides the outside one. The lowest distributed water as I have said before is at 200-feet level, and it encircles the whole of the Bagshot district. I propose only one set of pumps for the whole district. Then there is another level of distribution at 380 feet, and from all these there are small streams to the right and to the left. By that means of distribution the sands will be able to absorb more than double the water that I propose to bring to them.

5848. Where do you propose to tap it?—I propose a conduit to London to run along the Hogsback to Norwood, and from that point it is 36 miles to where it crosses the London and South-western Railway near Foxhill. When once the water gets to that point it runs by gravity to Norwood, where it is on a level of 210 feet above Ordnance datum. The red line represents the lowest catchment on the east side, and the other lines represent the lowest catchment on the west side; they are all intended to be sunk at least 10 feet below the present saturated line or existing water level, and they completely encircle that space, so that there is no possibility of the water escaping.

5849. (*Mr. Harrison.*) Do you get down to the London clay there?—No, the London clay is underneath, and it holds up the water at present which depth is measured by the wells of the district.

5850. How far is the London clay below where you are?—I am not sure, it is a considerable distance below, but we have an impervious stratum before we come to that, and upon which I rely to prevent escape. It is pure sand, but it is saturated with water. The water that we put upon it cannot penetrate through the saturated sand, and it can only find its way out in a lateral direction. These conduits being sunk at a greater depth than that must intercept the water. There is a catchment applicable to each main drain, and from those catchments we run up drains at right angles to the catchments. The character of those drains is explained by this section (*producing a section, and explaining it to the Commission*). There are a certain number of holes all along the crown of the arch of the drains in the line of that vertical bed of stone. These stones allow the water from a large area to trickle into the drains. The conduit has various falls, some 10 feet per mile, and others less. The minor drains are proposed to be 20 feet deep, and there are 100 miles of them. By these means the water is absorbed in both directions, having lain in the sand upwards of 12 months, gradually finding its way into the drains. I have tried some experiments which prove that there is a slight current in the water when the saturated plain is inclined 1 in 80. The method of distribution is shown on this plan (*producing a plan, and explaining the same to the Commission*).

5851. Having explained the process of taking the water from Teddington to Bagshot Heath, and distributing it on the sand, and your mode of tapping that basin for the purpose of conveying the water to the metropolis, will you state by what sized culvert you propose to carry the water?—The London culvert for 36 miles I propose to make of 14 feet diameter.

5852. That is to be covered all the way, is it not?—Yes, that is to be covered all the way. I at first proposed that it should be 18 feet, but 14 feet will give 200,000,000 gallons a day, and if you ever require more, there can be another conduit of the same size made alongside of it. There are only three syphons in the whole of that conduit.

5853. What is the dip?—About 130 feet. I have estimated the cost of viaducts in those three instances, and I am much inclined to say that viaducts ought to be constructed instead of syphons; the conduit would then have a uniform fall the entire way of one foot per mile up to Norwood.

5854. And at Norwood you propose to have a reservoir?—Yes, a service reservoir partly covered and partly open.

5855. Of what area?—80 acres; the covered part to hold half a day's supply, and the uncovered part $2\frac{1}{2}$ days' supply.

5856. What proportion of the reservoir would be covered?—The whole is three days supply, so that it would be one-sixth covered. The object of doing that is that the water may always run through the small reservoir, and that will keep it cool and pure, and in case of emergency the water that remains in the uncovered part might be used.

5857. What height are you there above high water?—212 feet above Ordnance level.

5858. Where do you propose to take it from Norwood?—To Hampstead.

5859. What is the difference of level between Norwood and Hampstead?—Hampstead is a few feet lower than Norwood.

5860. Is Norwood sufficiently high to give you the necessary head to carry it to Hampstead?—Yes.

5861. Will you describe to the Commission the means which you propose to adopt to carry it from the one point to the other?—When I got the water to Norwood I saw there was great difficulty in distributing it. If you bring water to one end of a large place like London, and have to send such a volume of water as is proposed all through London, a great number of new pipes and mains would be necessary, and a great loss of head would be the result. I propose that there should be one large main to run right through London, 10 feet in diameter, made of wrought-iron, or an equivalent in two mains.

5862. You must have a considerable dip?—It runs down to the Thames and up to that part of Hampstead. There may be a difficulty near the Thames, but the rest is very simple, and the object to be attained is so important that any difficulty that may arise may be met.

5863. It must be an immense syphon?—Yes.

5864. What is your head of water at Norwood?—At Norwood it would be 212 feet, and at Hampstead we should take off 12 feet. The object of that is this: by putting down a syphon, and vertical pipes to connect with existing mains, they are at once doubled in power, because you send a flow of water in both directions.

5865. At what point do you cross the Thames?—Near Chelsea.

5866. Would you take your main pipe over or would you tunnel under the Thames?—I am disposed to say that it ought to pass over the Thames.

5867. On one of the bridges?—No, by a new bridge.

5868. Would you have a series of pipes?—Yes, I think it ought to be a double pipe; the pipes to make in themselves the bridge crossing the Thames.

5869. What is your estimate for your structural works, commencing at Teddington to Bagshot, with your distributing mains and pipes, and your tunnel from Bagshot to Norwood; and will you give the estimate separately if you can from Norwood to Hampstead?—I have estimated the works very full; and for conveying the water from Teddington as I have described, irrigating the sands, and collecting the water, and the construction of the conduit to Norwood, including the reservoir there, the estimate is 5,000,000*l.*

5870. And what is your estimate for the works from Norwood to Hampstead?—Over 1,000,000*l.*

5871. Is that including the reservoir at Hampstead?—Yes, but that does not of necessity form part

T. Macneill, Esq.

27 June 1867.

of the scheme. The water may be distributed from that reservoir as from any other.

5872. And what is the total estimate for all your works up to the distributing mains in the metropolis?—I do not estimate anything further than the bringing of the water to the reservoir at Norwood. I do not propose to go into details for anything further than that.

5873. How do you propose to raise the funds?—That I have not considered.

5874. You have no idea as to any special mode of raising a fund of 6,500,000*l.*?—No, I have not. I consider that London wants a good supply of water, and that it would not be easy to get it from any other quarter than the Thames or at a less cost.

5875. Has it occurred to you whether the advantages are equal to the outlay involved in taking the water back from Teddington to Bagshot, with all the costly arrangements for distributing the water on the sand in order that it might be absorbed, and then taking it back again to London in an expensive tunnel, as compared with tapping the Thames at a lower point, and forming filter beds for the purpose of purifying the water?—I have fully considered that.

5876. What is the contrast?—The contrast is very much in favour of what I propose, as far as my judgment goes.

5877. Do you mean as to cost?—No. Supposing the water were raised from the weir at Teddington now, and it were fit to be used in London, and it were raised and pumped up direct to the reservoir at Norwood, it would require practically the same amount of pumping power to do that as to bring it the whole way to the Bagshot Sands and back again to London. That seems a contradiction, but I will explain why it is not so. There is a large quantity of water that comes down at Guildford which is added to the Thames water, and at the point named, Horsell it joins the Thames water in the Basingstoke Canal at the 68-feet lift.

5878. Do you mean to say that your four lifts are not more than would be necessary to raise the water to that point?—One-tenth more, simply because you must use iron pipes to raise the water direct at Teddington, and an iron pipe requires more fall per mile than a large brick culvert, so that what you gain in the short distance you lose by the greater fall.

5879. Surely if you cut off the structural expense of this work from Teddington to Bagshot, and get rid of four distinct lifts and all the network of pipes and catch drains, or whatever you call them, in the sands, as well as the return to Norwood, the cost of carrying the water from Teddington to Norwood must be very much less than the plan which you suggest?—No doubt, but I say that the engine power required and the annual expense of pumping is not much greater.

5880. What engine power have you for those four lifts?—I have divided the engine power into three. There is first the bringing of the water from the Thames to the sands, which requires 7,000 horse power, to which I add one half, which makes 10,500 horse power.

5881. (*Mr. Harrison.*) That is the accumulated power of the different engines for the different lifts?—Yes. There is first the Bushy Park lift of 30 feet, there is another at Weybridge of 85 feet, there is another lift further on in the canal of 68 feet, and that brings the water on to the sands. The united power of that is 7,000 horses, to which I add one half, which makes it 10,500.

5882. (*Chairman.*) What power would be necessary to lift the same quantity of water from Teddington to Norwood?—Before answering that I had better say that more engine power is required, because that only brings the water to the sands, and to distribute it requires an extra power of 6,000 horse power, one-half, as before, being added for duplicate power.

5883. Then that would be 16,500 horse power?—Yes; and in order to lift the filtered water from the lower conduit it takes 3,500, or in all 20,000 horse power; that is including the duplicate power.

5884. Returning to my former question, having regard to the same quantity of water raised from the level at Teddington to the height of your reservoir at Norwood, what power would be necessary to lift it?—The theoretical power required by the plan which I propose is 13,378 horse power. The theoretical power to raise that water from Teddington to the reservoir at Norwood is 12,000 horse power, and that is, as before stated, a difference of one-tenth.

5885. There is a difference of one-tenth in the power and all the cost of the structural works?—Yes.

5886. What is the advantage, therefore, of your system of filtration over the system of filtration which is now adopted by the companies at Hampton?—I cannot speak as a chemist, and must refer to the many quotations in the pamphlet describing the advantages. I have consulted Dr. Frankland, and he has authorized me to say that he shall be happy to conduct experiments, but they have not been conducted at present.

5887. But, speaking as an engineer, you invite us to take the water from Teddington to the Bagshot sands for the purpose of filtering, and then to bring it in an expensive channel up to Norwood. I ask you why you should take the water back so many miles from Teddington to Bagshot, 16 miles, and returning it necessarily 16 miles, making 32 miles of waste?—My answer to that is that if you take the water direct from Teddington I conceive that it is utterly unfit for the use of a town, whereas by the process I propose it will be delivered at a uniform temperature throughout the year and perfectly purified.

5888. Supposing it is subjected to sand filtration, which is all that your water is subjected to, with the exception of the mixture of peat which you call charcoal, what is the difference between the present process and the one that you propose?—There is in the first place 5,000 times the extent of filtration of the water by my process above ordinary filtration. The water is subject to the improvement which takes place by the growing of plants, which very much improves the water. The great fault of the water at present coming into London is its containing nitrates and nitrites, which, as I understand Dr. Frankland says, can be removed by the process which I propose it to go through. In fact the water, after undergoing that process, will not contain the trace of the sewage which it has now, and the water will always be of a uniform temperature; but to show the difference between the process now recommended and that of ordinary filtration I had better read some remarks of Dr. A. Smith on this point:—

"The power of sand to purify water is really very great. I tried a few experiments upon it, which I may as well mention. A strong alkaline solution of peat was made and passed through sand; the water came through clear, retaining only a taste of the earthy portion of the sand.

"It seem probable that there is here an action independent of the ordinary chemical affinities; but as far as the purifying of the water is concerned it is enough to know that it is a fact.

"It would not be correct to say that sand is the most powerful filterer in proportion to its bulk, it is too coarse generally to act except when there are large quantities, and other substances purify the water using much smaller quantities. It is however so general, and it is used in nature for purifying water so frequently, that it deserves most attention. The sand requires to be of considerable thickness, at least so that the water does not run too fast off; but at the same time nearly all the impurities removed will be found on the surface of the filter.

"Percolation through a porous stratum is capable, in fact, of removing any amount of organic impurities from water, as the universal admiration of spring water sufficiently shows; and this removal of the organic matter, which is an objection to surface water, has generally been considered a sufficient compensation for the inorganic matter and hardness which it has acquired in the process by going down to great depths and remaining a long time. It is true, that to remove the last traces of organic matter seems to require that the percolation be continued a considerable length or space.

"It happens here, as in other cases, that the purity is according to the extent of the process of purification." * *

"From the manner in which I find this paper has been written it will be better that I should give a short abstract of what I believe true on the subject.

"The Surrey district is composed of sand and shingle, with a thin covering of heath.

"The water from it is soft, varying from one degree to six degrees of hardness.

"The nature of the surface renders it exceedingly fitted for natural filtering, or purification by drainage through the substratum.

"This is the mode in which the purest waters are obtained, and by which the purest waters are got from peaty districts.

"This mode of slow filtering removes all organic matter from solution, so that the organic matter on the surface is a matter of less importance, as it is remedied by drainage.

"This is the method by which spring water is prepared, and by which it is aërated, or supplied with carbonic acid and oxygen.

"This water might be supplied to towns without filtering, unless by some unforseen circumstances it might be somewhat diminished in brilliancy during its flow.

"This has an advantage over the river water in softness and in absence of organic matter, which qualities must be produced by artificial means when river water is used.

"The comparison in expense and practicability must be a matter for further investigation.

"This mode of filtering removes iron in the state in which it is found in parts of the district. As far as surface is concerned, the district in Surrey is peculiarly fitted for this mode of purifying water.

"Water so purified could become nowhere putrid from want of the material which putrefies. Peaty matter itself does not putrefy: even if it were not removed there would be very little organizable matter, much less than in the neighbouring rivers.

"Reservoirs with water thoroughly purified would not become filled with vegetation in the light or in the dark. To prevent water from putrefying, pre-supposes putrid matter. Water should not be supplied with such matter in it.

"As little rain as possible ought to fall into reservoirs; unless, perhaps, many miles from towns, the impurity of the rain, even outside of towns, being very great.

"It may be objected that water so pure as this cannot be got; and this brings us to another reason, the reason which seems to me most in favour of covered reservoirs, arising from the impurity of rain got from the neighbourhood of towns. This impurity must be very great near London, and probably several miles from London. I have just been collecting water from the fields a mile from Manchester, and about two miles from any large chimney; it is very impure, and of a bad taste; it could not be used as a supply for a town without careful filtration. I reserve the description for another occasion. It would be an important thing to know at what distance from London it would be safe to leave reservoirs uncovered, and whether at any distance whatever a large amount of rainfall would be an injury. It would probably be refining too much to speak of any injury to distant reservoirs from rain; but as to supply reservoirs in the neighbourhood of the town it would not at all be over refining, as the amount of impurity is very decided. If the water could be got so pure as not to require filtering, then the reservoirs at the town would not be wanted, or at least diminished to a very small size. If it should be found that filtering cannot be dispensed with, the removal of filters far into the country will, I believe, be an improvement, as in that case they will get the water in a clearer state, and have less duty imposed upon them." * * * *

"Water purifies itself from organic matter in various ways; by forming nitrates, as in sewers, and in the neighbourhood of cesspools and churchyards, under streets, in manured grounds, and other repositories of organic matter.

"This may be done in a laboratory on a small scale, where animal matter by means of a sand filter, may be converted into nitric acid.

"In the larger operations of nature the carbon also is oxidized.

"Sulphurated hydrogen is also oxidized on a small scale by a filter, being converted into sulphuric acid.

"A filter, therefore, as an oxidizing agent, acts in proportion to its cubic contents.

"Water falling on the surface of the ground gets rapidly saturated with organic matter; but in passing through the soil gets filtered, and the matter oxidized, making the porous soil and the air the great agents of purification in a country; whilst drainage will act in removing organic impurity as well as mere water." * * * *

"This growing of plants and animals is, therefore, a good mode of cleansing water, when space and time are abundant, as in the larger operations of nature, but unfitted for waterworks where neither are very ample." * * * "The hard water will, of course, be better able to feed land with its soluble manures; or, if we choose to express it otherwise, the plants will more readily feed, finding the food more soluble."

And he gives the following description of the filtering district proposed for purifying the Thames water:—

"I shall describe the state of the heath as far as relates to natural means for purifying the water. The district is covered by sand, or by shingle if it may be so called. This sand is a reddish brown, and in some places has a considerable depth. On the surface is heath. The upper forming the soil of the heath is composed of peaty matter and sand; the peaty matter gives the blackness. When the peat is washed away the sand is found to be a pure white. In many places where the plants have been removed and the rain has begun to wash away the peat, the mixture of the two gives a peculiar colour to the ground, a grey with a tinge of purple in the distance. Sometimes the peat is found entirely removed, and then the sand or flints are found perfectly white, shining on the surface. The reddish sand lies immediately under it, and this effect has been produced merely by taking off a few inches, a mere scraping from the surface. The sand of the surface mixed with the peat is evidently washed white by the acid of the peat, and it is remarkable how decided this line of white and red is over the district. The soil is such a good filter that none of the acid goes much below the surface, so that there is no white sand to be found above a few inches deep generally, as far as I saw, about eight inches, although there were cases where it was not so deep, and also cases where it was two feet deep. As the upper sand must retain matter in solution to cause this whiteness, so the under sand not being acted on, it must be penetrated by water having no such matter in solution. It follows that the peaty matter must get filtered out before it passes from the upper layer to the under layer. It is then an interesting fact that at the junction there is a blackness, a black line in fact running along under the surface having white sand above and red sand below; it is in fact the line of filtration. It is an old remark that humus acts as a charcoal filter, although its action here, except as a strainer, is difficult to understand; the soil does seem to be formed of a mixed charcoal and sand filter, which does its work very effectively all over the district.

"The sand above is found to be saturated with water, while the lower sand, not more than a couple of inches from it, is only damp, showing that the water passes through very slowly, and so has time to undergo the process of filtration, which is not a mere straining through a sieve, but an act of purification. The black line which is an accumulation of carbonaceous matter is a considerable hindrance to the passage of the water. This will perhaps account for the great part of the water in the streams, at least in the Bagshot district, being surface water, as the water will have a greater facility for moving forward above the line of filtration. If the water in the ponds is in many cases water which has passed through the soil, and been thrown out by impervious formations, it will account for the greater freedom from a peaty taste and also for a greater hardness than is found in the streams.

"It might be asked if this filtering removes the iron, and the answer is already to be found in the wells and springs; if the iron is in combination, as I believe it is in most cases, with peaty matter, they will be removed together. At any rate they are both removed. Professor Way has removed many inorganic salts by clay and soil, and shewn that they are absorbed by clay especially in great abundance.

"But to obtain these results the water must be allowed to pass through the upper stratum; thus the filter, instead of occupying only a few acres, straining the water from its grosser impurities, will be a thorough natural purifier, where the water will be elaborately cleansed by the ordinary natural processes which form the best spring water. The water in that case will not be allowed to stand so long on the surface and become impure in contact with the surface; this will prevent evaporation such as occurs in some parts of the district where there is a stagnant water, it will also prevent the necessity of extensive artificial filtration, which the use of this natural filter, will to a great extent, if not entirely, supersede. * * * *

"Water taken above the point of filtration, that is not having passed below this stratum, contains much organic matter; but below this line it is true drainage water, and is purified like water from a shallow spring. Leaving the cause for examination elsewhere, these facts lead to the conclusion that the power of filtration to remove colouring organic matter in solution is really enormous: but it must have time, as the action is not a mere straining through a

T. Macneill, Esq.

27 June 1867.

sieve; the artificial filter is for this reason generally too small for the full effect obtained by the natural mode of filtration, where time is given for a complete act of purification.

* * * And in answer to the question, "Even if little or nothing were done either on the surface or with the mode of collection, we are to understand, then, that the supplies drainable from the greater portion of these Surrey sandy districts would be on an equality with the soft water supplies of the northern towns you know of, as at present collected and distributed to them?" he answers: "Yes, certainly."

5889. (*Mr. Harrison.*) Do you expect that the filtration will reduce the hard chalk water to soft water?—Yes.

5890. Can you speak to that from positive experiments?—No; but I may say this, that the water of the Thames added to the water of Guildford in their relative proportions reduces the mean hardness of the water, before spreading over the sands, to 8 degrees from 13 degrees, which may be considered as the average of London water.

5891. (*Col. Harness.*) The river Wey is very nearly pure, is it not?—The water of the Wey is very soft.

5892. (*Mr. Prestwich.*) The mass of sand through which you would propose to filter the water forms, does it not, the upper Bagshot Sands?—The upper and the lower.

5893. And they are from 100 to 150 feet thick?—The upper sands would be about an average of 130 feet.

5894. And that is covered over in a part of those hills by gravel and peat?—Yes.

5895. Therefore, you believe that there would be a tendency to remove all organic impurities in the water passing through so large a mass of sand, covered by peat and gravel?—Yes.

5896. From your own knowledge, have you any reason to suppose that the carbonate of lime and the nitrates would be removed by such a process?—No, not from my own knowledge; and it is of no use referring more than I have done to chemists' opinions, which I have quoted in the pamphlet that I have handed in, because all that I could say is second-hand; but judging from people who have examined the question, I should expect a very great reduction in the hardness of the water, besides the total removal of all the impurities of the Thames water.

5897. But the instances that you give in this pamphlet do not apply exactly to your own case?—No, nor do I think I could find any instances. The way to find it is, as I have suggested, to get Dr. Frankland to examine it. I have spoken to him two or three times about it, and I can say, from what he has told me, that I have a still better opinion of the scheme than I had before I spoke to him. An experiment could be tried very easily on the district by passing the Thames water throught it with a proper proportion of Guildford water. The canal comes from the Thames and passes through the district, and it would be very easy to prepare a small district in the way I have proposed, and to pour over it the Thames water brought by a barge; it would not require a very large district to determine the question.

5898. You have never heard of any instances where passing calcareous water through siliceous sands would result in the removal of calcareous matter?—No, not through pure sand, but I have heard of instances where it has passed through clay and peat.

5899. (*Col. Harness.*) The water you find in the canal is not Thames water, is it?—No, I would bring the water up the canal and prepare an acre of ground, or a larger space if necessary, and throw over it the proper complement of this water, and drain it off afterwards, which would prove the quality, and also, if I am not much mistaken, that there would be no waste.

5900. (*Mr. Prestwich.*) The total area of the Bagshot Sands, which you have taken as a filtering ground, I see on that map are marked, one 25 square miles and the other $22\frac{1}{2}$?—Yes.

5901. The rainfall in that district is about 25 or 26 inches, is it not?—I have estimated the average as two feet; the maximum is 26 inches.

5902. A large proportion of which would pass into the Thames, the gravel being so porous?—Yes, that is so at present. I have assumed over that area of 47 square miles that two thirds of all the rain water will be caught by those conduits, which will be pure rain water.

5903. Apart from your own plan of bringing the water there, have you ever estimated what the rainfall is upon that area of 47 square miles?—Yes. I calculate that the available water due to the rainfall of the 25 square miles would be equal to 16,000,000 gallons per diem.

5904. How much of that is delivered in the streams and watercourses of the district at present?—I cannot say that.

5905. Is not the quantity excessively small? Are not the streams all very small in that district?—The streams are not subject to floods, but I am not aware that the streams do not give out the full proportion of rain water that falls upon the district; some no doubt sink to the saturated line, but on account of the absorbing nature of the district there are no floods on those rivers or streams.

5906. Is not the lower portion of that mass of sand so saturated that it is full of small springs, the water of which is lost by evaporation?—No, I should not say that, as much of it would sink into the lower bed.

5907. For example, take the district between the village of Chobham and the Frimley Ridges, where there is a large extent of heath land; is it not the case that a certain portion of the rainfall which falls upon the Frimley Ridges, which you take as your filtering ground, passes off in a stream which uses that piece of ground?—There is a stream which comes from the Bagshot Sands in that locality.

5908. Have you ever gauged that stream?—No, I have seen many gauges taken of it.

5909. You are probably aware that experiments were made upon all those streams in the year 1852?—Yes, by several engineers.

5910. And the result was, I believe, that the delivery of water from that mass of sands was found to be very limited?—Yes, I think that was so.

5911. If you have walked over the moors in which this stream rises you would have found that the cause of that is that there is no large spring, but the ground itself is excessively marshy and a very large amount of evaporation goes on?—Yes, but I think there is another cause, and one, perhaps, which is even more true than that, namely, that as soon as the water falls into the sand of the lower beds it never comes up again; it gradually goes down an inclined plane till it finds its way out at some place down here on the Thames (*pointing to the model*). My experiments would lead me to think that that was the case.

5912. Is there not a bed of very hard laminated clay in the middle of the Bagshot Sands which holds up the water between Knapp Hill and Frimley?—There is a bed of clay there.

5913. Do you know the Hermitage?—Yes, perfectly well.

5914. Do you know the brick pits there?—Yes.

5915. Does not that bed of clay pass underneath the whole of the district which you take as your filtering ground, this bed of clay being part of the Middle Bagshots?—There is a bed of clay that divides the two sands, the upper and the lower, and that is where all the springs of the upper sands burst out. I expect a large supply from there, and for that reason I have laid out a conduit to encircle it. I have a yellow line on this map (*producing another map*) which shows the line dividing the two sands, the upper and the lower, which line shows a bed of clay of various thickness, said to be from 2 feet to 14 feet. Of course a large quantity of water which is thrown upon the upper sands would come out there, and I have on this plan shown how this water would flow into the main conduit; the rest from the upper sands

would be drained off by the centre tunnel and line of shafts as shown on the model.

5916. The difficulty, as it strikes me, is this, you now see that your collecting ground is very near the outcrop of this bed of clay?—A portion of it is.

5917. Notwithstanding that, the rainfall on the upper sands is very large, and that the bed of clay comes to the surface just at the foot of those hills, and notwithstanding that there is so much water lost oozing through those sands over a large surface not being directed into any one given channel, in the form of springs, the delivery of the water from those upper sands into the streams is excessively small?—Yes. I believe when this water passes over the clay bed much of it sinks into the lower bed of sand.

5917*a*. Therefore it would appear that you would experience a similar difficulty if you were to deliver any large quantity of water into the sands, namely, that you would not be able to collect it, that the water would ooze out on the large surface of moorland where you would find extreme difficulty in collecting it; and you have not made it apparent that you would be able after passing the water into the sands to catch it again?—I quite see what you mean, and I am quite prepared to show how the water could be collected into those channels. It is a question of draining. If you have drains connected with the deep wells, as shown on the model, running through those sands, not shallow drains but deep cuts, with a vertical wall of stones and coarse sand, it will act on both sides as a receptacle for the water to run into the conduits, and I believe, of necessity, the water will have a preference to fall into those artificial streams to seeking another outlet if that outlet has not a greater fall for the water than the one which I propose artificially to give it, because the water and the sand is all one homogeneous mass in the upper sands; so that it is a question of the degree of facility that you can give for the water to get away. If there were clay running through it it might be a different matter, but it is perfectly pure, and all you have to do is to place in that sand a sufficient number of drains and wells which will collect all the water that is thrown upon them, and if any escape at the margin of the clay bed it will be caught lower down.

5918. At present all the rain water which falls on those sands must find its way out, and does find its way out by passing underground a great distance?—That was the lower sands which I mentioned.

5919. With which you have nothing to do?—Yes, I have.

5920. You confine your works to the upper sands, do you not?—No; to the upper and the lower; the greater quantity is the upper.

5921. But you said the lower just now; your plan has nothing to do with the lower sand?—Yes it has, as a large part of the proposed filter is on the lower sands.

5922. You were speaking of the lower sands being saturated with water, but are you acquainted with the well which was sunk at Mr. Waterer's, just at the edge of the middle sands, near Chobham?—No, I have not seen it.

5923. You probably are not aware that they went through the sands and through the London clay, but they could not get any water at all?—I can believe that. As far as my judgment goes it would be impossible to get much water from any one well sunk in these sands with the present limited rainfall, as the incline of 1 in 80 before mentioned from the bottom of the well to the saturated plain would embrace only a small area.

5924. I mentioned that just to show you the difficulty of getting water out of these sands, whether the upper or the lower. Are you acquainted with the well also at the Woking station?—Yes, I know that; and beautiful water there is in one of those wells.

5925. But the quantity is not large?—No.

5926. Are you aware that they are sinking a well on the very top of the Frimley Ridges to the west of Bagshot?—They have gone down very far and have got no water, but I am rather glad that that is the case, because throwing water into the sands here which are now destitute of water would enable such a well to give an abundant supply of water; it shows that there is nothing to prevent the water getting out. It is because of the great purity of the sand that the water runs away.

5927. It would appear to me that it oozes out in such innumerable directions that you could not collect the water after you had thrown it on to the sands, because there is no district round London where there is more difficulty in getting water by wells in those sands than in this very Bagshot and Frimley district?—But there is no instance of sinking wells where you do not come to water by sinking down a certain depth. It is very probably the case that the sand is so dense, that the water trickles through it very slowly indeed. If you make those wells large enough, and make cuts out from them as I propose, you will get water if those cuts are made in a saturated sand, but by merely making a single well down into them, and leaving the water to come in through a small area, of course the water would be very slow indeed in coming in, but if adits are made from those wells I should take it that that would increase the supply very much. I am informed by the contractor who made the railway cutting through these sands that he met with a large volume of water, which I quite believe, for he had here a lengthened cut in the saturated sand.

5928. There is another point to which I wish to direct your attention. Do you know the village of Normandy to the south-east of your district, between the Hogs Back and Box Hill?—Yes, I know the district.

5929. That is where the water of the Middle Bagshot Sand which holds up the water of the mass of sands which you would use as a filter oozes out, and it is a very marshy tract; do you know the character of those waters?—I do not.

5930. Do you know that they are extremely ferruginous?—I do not.

5931. Are you aware that there is a bed of greensand at the base of the upper sand, and at the top of the lower, which contains a great deal of iron pyrites which decomposes and tends to impregnate much of those waters with iron?—I am aware that there is a little iron in the district, but that it was of any extent I was not aware.

5932. And also several of those streams between Chobham and the Frimley Ridge are in the same condition?—Within the district that I encircled there is very little iron.

5933. There is a spring between Chobham and Frimley Ridge which was so ferruginous that it was contemplated some years ago to use it as a chalybeate water, and it is within the area which you have taken?—If there were any small area of that sort which was impure, I can conceive that it would be very easy to cut it out, but that the whole of the upper and the mass of the middle sands are pure I think is undoubted, so Sir Roderick Murchison told me, if I did not misunderstand him; and Dr. Franklin said that a little iron might not be any injury to the water of this district if there was found to be a little, and Dr. Angus Smith says: "It might be asked if this "filtering removes the iron, and the answer is already "to be found in the wells and springs; if the iron is "in combination, as I believe it is in most cases, with "peaty matter, they will be removed together. At "any rate they are both removed."

5934. (*Mr. Harrison.*) You propose to distribute a given quantity of water over an area of altogether 22½ square miles?—Yes.

5935. And your calculation is based upon your collecting the whole of the water again by catch-water drains?—Not all, I allow 10 per cent. for evaporation.

5936. And how much for waste otherwise?—I do not conceive that there will be any waste, I cannot see where there would be any waste.

5937. You base that upon the assumption as you

T. Macneill, Esq.

27 June 1867.

state it as a fact that your lower catch-water drains would all be in sand, which is now so entirely saturated and held up by the beds of clay which surround it that there can be no waste below the level at which your lowest catch-water drain is to be placed?—No, there cannot; whatever waste takes place now I would let take place, I would not interfere with the existing waste, but that water which I throw within those catchments I conceive will be all got again.

5938. Still the whole scheme depends upon that?—Yes.

5939. In the next place, one object which I presume you have in view is that by this complete filtration you would convert the hard chalk water into soft?—I should hope so.

5940. But you only hope so?—I have no proof of it, except so far as the mixing of the rain water and the Guildford water with the Thames water reduces it from 13 to 8 degrees.

5941. But that does not follow when you come to mix merely the rainfall of a small area with the enormous quantity of water which you have to pump there?—But the quantity coming in from Guildford is considerable. Then there is the canal, which drains a large district, and I propose to utilize that water, and taking the hardness of these waters and their relative quantities; the mean before filtering is about eight degrees of hardness by Dr. Clark's scale.

5942. (*Chairman.*) You stated, did you not, in answer to a question that was put to you by Mr. Prestwich, that the general reason why so small a quantity was finding its way from that area through the river and the channels from the sand was that it was secretly finding its way to the Thames in some other quarter?—Yes, that is what I believe.

5943. What guarantee have you that of the water which you bring from Teddington and pour on to those sands a large proportion may not find its way secretly out and not be caught in the channels which you propose to collect them in?—I base my proposition upon this fact, that those conduits will be sunk below the present escape of the water, that is to say, 10 or 12 feet, or more if necessary, below the levels at which those waters are now oozing.

5944. Then you have detected the source of escape?—No, it is not an escape, it is oozing; there is no one place that I am aware of where the water runs as an escape, but there is a tendency in the water to fall from a high level to a low level, and I have proved that 1 in 80 gives a visible motion downwards.

5945. (*Col. Harness.*) Then do you draw a line of 1 in 80 to the nearest point and intersect that line?—Not quite that. I would sink wells along the line of catchment in the first instance, and by that means the water in the wells gives the saturated line, and below that line I would sink the encircling conduit.

5946. (*Mr. Prestwich.*) In the section which you draw on your plan you say, "line of saturation held up by the London clay;" are you aware that that is a mistake?—No, that line indicates the saturated line when the conduits are at work, or more correctly speaking, is the bottom of the filter.

5947. You admitted just now when I pointed it out to you that in the Middle Bagshot Sands there would be sand mixed with a considerable amount of clay which holds up the water, and it is those middle beds is it not, which hold up the water in your filtering district?—That is as far as the upper sands are concerned, but the filtering extends beyond that very considerably; the lower catchments are not in that.

5948. According to your plan, is it not limited to the upper sands?—No.

5949. Just confining yourself to the upper sand, that is the largest proportion, is it not?—It is about half I think.

5950. I want to prove that it is impossible for any water to pass underground from that district and to escape unseen by the Thames, because the rain water in those upper sands are held up by those middle beds?—Yes, that is so, and entirely agrees with my proposition and views, and I regret I did not see the drift of your question before, but I confounded the middle beds of clay with the lower beds, hence my want of a clear explanation.

5951. Don't those middle beds crop out immediately to the east of all your filtering district, by Chobham?—The lower catchment is on the east of the outcrop at Chobham.

5952. As they are impervious, is not all the rain water that now passes into those upper sands held up and delivered at that point?—Precisely so; so far as the upper sands are concerned it is all delivered along that line.

5953. So much so, that past that line you get into the lower sands, and you find no water at all from the upper sands finds its way through, because in the case of other wells which I have just pointed out to you, at Mr. Waterers and at Woking, they had to sink to a depth of 100 feet or more before they found water; so far, therefore, from being saturated with water, very little water passes from the upper sands to the lower. Those wells being so dry, show that there is no large quantity of water, as you would suppose, passing from the upper sands into the lower sands?—I suppose that all the water which falls upon the upper sands is caught by this bed of clay, and is thrown out at certain points all round, and all the water that falls upon that and no more escapes at those points. With regard to the water below that, the wells show the saturated line in that district, and those wells, as far as I have been able to go all round, are not more than 20 feet deep.

5954. The well which is in the lower sands at Woking station is 120 feet deep?—I think that the well in Woking cemetery is only 18 feet deep; the man who made it told me so, and also that it did not vary two feet in winter or summer.

5955. But that is in the upper sands, is it not?—No, that is in the lower sands.

5956. It is just at the base of the upper sands, and goes into the middle sands?—That may be so, but I am not aware of any well in the district which I have encircled, and in the line of the lower catchments, that is deeper than from 14 to 20 feet; if it would turn out otherwise my views on the subject would be very much changed.

5957. You have just mentioned that in Mr. Waterers and the well at Chobham Place, they passed through all three and got no water?—I know the upper sands has no water, but the lower ones hold the water up much nearer the surface.

5958. If you examine those wells, the experience derived from them is not at all favourable with regard to the capacity of the lower Bagshot Sands for holding water?—For yielding water it may be so, but my investigations and inquiries have led me to the belief that the water is near the surface along the line of the lower catchments, and in the pamphlet I have sent to the Commissioners I make the following observations: "At a depth, on the line of the lower catchment, of "about 20 feet below the surface of the sand in the "filtering district, the stratum is saturated with the "water held up by the London clay. This plain of "saturation is now in balance between the amount of "rain water and the resistance it has to overcome in "its downward course to the Thames, and a conduit "sunk in or below this saturated plain would collect "all the water now escaping, in addition to the Thames "water, which may be thrown on the sands, and the "four main collecting conduits shown on the plan are "supposed to be sunk below this line. Its exact level "can only be ascertained by boring, but judging from "the wells in the district, the water of which represents the saturated line, there will be no difficulty "in placing the collecting conduits at such a level as "will effectually cut off the escape of all waters from "the filtering district."

The witness withdrew.

PETER WILLIAM BARLOW, Esq., examined.

P. W. Barlow, Esq.

27 June 1867.

5959. (*Chairman.*) You are a civil engineer are you not?—I am.

5960. Have you turned your attention to the question of supplying London with pure water?—I have, with water from the chalk more particularly. Some 15 years ago when I proposed a plan I believed that the ultimate solution of the difficulty of supplying London would be found in the chalk, and there is nothing which has occurred since to alter my opinion, for reasons which I will explain if the Commission will allow me. I am not prepared with a plan, but the plan which I propose is so simple that it is rather a question of principle than a question of detail. I may mention that in the construction of the North Kent railway I found that large quantities of water were flowing into the river from the chalk on the side, and I was led to look to this from the fact that you have no streams on the surface there. From Lewisham down to the Medway you have only one stream, which in fact gets its source out of the chalk district. Then it occurred to me that there must be a great quantity of water escaping somewhere, and upon examination I found several powerful springs, and one single series of them, which I measured with Professor Anstead, delivered no less in our estimate than 7,000,000 gallons a day; and those series of springs are very nearly all lost before they come to the river.

5961. (*Mr. Prestwich.*) Where were those springs?—At Springhead, near Gravesend, which is known to visitors at Gravesend. There are a number of springs there which become quite a little river, and they are nearly all lost before they reach the river Thames.

5962. (*Chairman.*) Lost in what?—Absorbed in the ground, and they come out again on the sides of the Thames.

5963. Do they go into the chalk again?—Yes. My idea is, that a fault or something of that kind is the means of rendering the soil impervious there, and it throws them up, and they afterwards find their way down again, for they very nearly disappear. I could now measure from actual springs something like 10,000,000 gallons, which is one-tenth of the supply of London, upon that small bit of chalk district, and the amount of district which that represents is not above one-twentieth part of the whole of the chalk district surrounding London.

5964. Do you include the Watford chalk in that district?—Yes; when I say the chalk district I include the Watford chalk; you would have about one-third of the district of Kent on this side of the Medway, or about half as much as there is on the other side. I examined the thing with Mr. Anstead, and we certainly were of opinion that, looking at the experiments which had been made, there would be 60,000,000 gallons a day to be obtained by simply driving a tunnel 20 miles long from Lewisham down to Gravesend, or a little beyond, and I have had no reason to alter my opinion. At the same time there are so many eminent men now, who are opposed to my views, that I fancy I may possibly be wrong about this, but I am unable at present to see that I am wrong. That quantity only represents one-twentieth part of what the chalk would supply altogether; therefore, if you know how to get the water in the chalk, I think you may get a larger supply from it. The question is to know where to intercept the water. I am quite aware that in places you may go and get no water at all; for instance, take Brighton. Brighton is supplied with water from a very small area of chalk, yet close by they sunk a well and they could not get any water at all. The fact is that water does not flow all over the chalk as it is supposed to do in sand, but it goes in certain fissures, and those fissures must find their way to the river or to the sea, and therefore the way to intercept the water is to drive tunnels by the side of the river or the sea. That is the view which I take. The exact direction of the tunnel that I have referred to I do not think is important, except that it should go parallel to the river.

5965. (*Col. Harness.*) You think that the water from the chalk does not find its way to the river on the surface but underneath?—Yes; you do not find the water everywhere on the top, and you cannot expect to find it everywhere underneath. It follows certain fissures in the chalk, and if you know where to look for them or where to intercept them coming to the sea, you are pretty sure,—in fact I may say almost certain,—of a large supply.

5966. (*Mr. Prestwich.*) You would intercept a good deal of what would be the rainfall upon the North Downs as it escapes underground to the river?—Yes.

5967. Can you state what extent of surface that would represent?—The extent of surface on the east of the Medway is 320 square miles, and the infiltration which we reckoned was 8·44 inches, which was the result of experiments made upon a small scale for the purpose of testing it. I believe that the infiltration is really more, but I think it is important to make experiments on a much larger scale than was done. 190 miles, allowing 8·44 inches, would produce 60,000,000 gallons per day west of the Medway, 320 square miles east of the Medway would produce 100,000,000 gallons.

5968. In fact you mean by west between the Medway and Bromley?—Yes.

5969. You stated, did you not, that you calculated upon collecting 60,000,000 gallons a day by means of a tunnel from London to Gravesend or to the Medway?—Yes, a tunnel which will run parallel with the river.

5970. But you could hardly expect to collect the whole quantity, especially that portion which passes off in springs and streams which now flow into the Thames, such as the Cray and the Darent?—This 8·44 inches is assumed to be the amount that is left; the whole rainfall is 26 inches or something of that kind.

5971. (*Chairman.*) Do I correctly understand that you met with a very prolific piece of chalk, and you applied that rule of measurement for a distance of 20 miles, giving a certain result?—No; what we found was the result of 30 miles at the back of it, it was not the production of that particular spot; that spring of 7,000,000 gallons must be the result of a good many square miles of accumulation at the back of it.

5972. What is the basis of your calculation, that you would realise 60,000,000 gallons a day?—Out of the whole rainfall, which is about 26 inches, we get 8 inches.

5973. How do you ascertain that 8 inches would be available as a water supply?—Observations and experiments have been made to show the infiltration, and I have seen the observations of Mr. Robert Stephenson for instance; he made it a much higher amount, and Mr. Homersham considers that it would be a much higher amount than that. There may be an error, and therefore I say that there ought to be experiments to ascertain it more particularly; but assuming that you get half or only a quarter of this estimated amount you have a means of supply which I do not think can be found by any other method.

5974. (*Mr. Prestwich.*) There is evidence, is there not, since your paper was prepared, that several large wells have been sunk along that line, from which a considerable quantity of water is derived?—Yes as regards the East Kent Waterworks; since that time the river which they have to depend upon has, in a great measure, disappeared, and they depend principally upon a well which they have sunk where Mr. Prestwich pointed out that a fault rested, and where they ought to get some water, and they really are getting their supply principally from that very source.

5975. They are getting several million gallons a day from that source, are they not?—Yes.

P. W. Barlow, Esq.
27 June 1867.

5976. Is there not a well at Deptford from which they get 2,000,000 gallons a day?—Yes, I have heard that they have a large quantity in their wells at Woolwich and all the way down, but I do not think that wells are so certain a mode as of driving a heading, because all this water must find its way into the river somewhere between high and low water mark, and therefore I think you are sure to get hold of the greater portion of it.

5977. Did you not notice some strong springs in the river at Erith?—Yes, at very low water you see them.

5978. (*Chairman.*) Are you aware that at Crossness they sunk a well 880 feet deep in the clay and they found no water?—I was not aware of that. They found no water at Brighton, although within a mile and a half they get supply enough by driving headings. I do not think that sinking borings or wells is the way to make sure of obtaining water.

5979. (*Mr. Prestwich.*) Did you ever gauge the Cray or the Dart so as to know what the delivery of those springs is?—I did not, and I forget what they are. One of them receives its water from the outside.

5980. But are there not some strong springs in the valley of the Darent, and you would have to deduct the delivery by those rivers?—Yes, but that would be a very small proportion. You get the floods from the river Dart, which takes its rise in the Weald of Kent, and you get immense floods from the Weald of Kent that go into the chalk.

5981. The Cray rises in the chalk itself, and there is a very strong spring near Orpington, is there not?—There is one river which rises in the chalk, but the Darent rises outside the chalk, and there is one river which flows up to near Sevenoaks, and the floods from there I should say counterbalance that. The floods come down, but they disappear, and there are no floods when you come to the chalk, so that you get the water from the land beyond in addition to the chalk.

The witness withdrew.

Adjourned.

Wednesday, 26th February 1868.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND, K.G., IN THE CHAIR.

Sir JOHN THWAITES.
Alderman Sir BENJAMIN PHILLIPS.
Colonel HARNESS, C.B.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

J. Quick, Esq.
26 Feb. 1868.

JOSEPH QUICK, Esq., examined.

5982. (*Chairman.*) Which of the metropolitan water companies do you represent?—The Southwark and Vauxhall and the Grand Junction companies, the one on the south side of the Thames and the other on the north side.

5983. In what relation do you stand to those companies?—I am engineer to both of them.

5984. Could you give the Commission the particulars of the supply which the Grand Junction Company derive in the first place, and where they take it from?—I can give the exact boundaries of the supply. The town district of the Grand Junction Company is part of St. James's parish, Hanover Square, Paddington, Marylebone, Kensington, and Hammersmith. Their country district is Acton, Ealing, Chiswick, Hanwell, Brentford, Isleworth, Hounslow, Twickenham, Hampton, Teddington, and Hampton Wick. Those are the districts supplied by the Grand Junction Company. The water is taken from the river Thames at Hampton into subsiding reservoirs, and pumped from there to Kew Bridge, on the Middlesex side of the river. It is there received into depositing reservoirs, and filtered and pumped again from thence to Camden Hill, Kensington, into a high-level covered reservoir, and pumped again to an additional altitude of 150 feet, for supplying the northern portion of Uxbridge Road, Tyburnia, and that portion of the district south of Oxford Street and Bayswater Road is supplied direct from Kew from a stand pipe 220 feet high; so that there are three lifts altogether—in the first place from Hampton to Kew, next from Kew to Campden Hill, and from Campden Hill again it is pumped 120 feet.

5985. What quantity of water does that company supply?—The maximum quantity of the past year has been 8,894,000 gallons per day, and the minimum quantity 7,500,000 gallons.

5986. Have you any means of getting at the population, and showing what that is per head?—The population amounted to 252,927, as far as we could get from the Registrar General's returns.

5987. What would that give per head?—About 34 gallons per head per day.

5988. (*Sir J. Thwaites.*) Is that nett, or do you make allowance for waste?—That is the nett quantity.

5989. When you divide the 8,894,000 gallons by the number of inhabitants is that the average per head?—That is the total quantity, including water for trade and all purposes. The quantity reduced for domestic supply would bring it down, perhaps, to about 26 gallons per head, allowing the difference for trade purposes.

5990. That is to say, eight gallons per head for purposes beyond the requirements of domestic supply?—Yes.

5991. Then the trade supply is not a large item for manufacturing purposes in your district, is it?—Not in the Grand Junction district; not so large as in the Southwark district. There are merely some two or three railway stations, and one or two small distilleries, but very few large manufactories consuming water.

5992. Have you had any complaints in your Grand Junction district as to the insufficiency of the supply?—No, not any that I am aware of. There may be an occasional deficiency, perhaps, in some house on account of some defect in the fittings, or something of that kind, but in a general way I do not think we have any complaint at all.

5993. (*Chairman.*) Have you always been in the habit of obtaining your supply from Hampton?—Since 1852.

5994. Where did you get your supply from before 1852?—At Chelsea, by Chelsea College, as near as possible at the eastern end; then we removed from there to Kew Bridge, and the water was taken at Kew Bridge. In 1852, during the inquiry into the metropolitan water supply, an Act was passed to compel all the companies to take the water beyond the tidal influence, and then it was that we found ground at Hampton suitable for our purpose, and we went up there.

5995. Has there been any result of the change with respect to the quality of the water or the difficulty of getting it?—There has been no difficulty in getting

it, we have an ample supply there, and no doubt the water is much better as there is less contamination.

5996. Has the quality been tested by actual analysis?—Yes; it was proved at the time before the Act passed that the water taken at Chelsea was liable to contamination from the enormous amount of sewage passing up and down the stream, and we were compelled within a certain time, I think within three years, to remove the source of our supply from where the pumping stations existed up to beyond the tidal influence, and Hampton was selected as the most suitable site for that purpose.

5997. Have you any analysis of the component parts of that water?—The water has been analyzed several times, and I think that there would be no difficulty in furnishing the Commission with the analysis.

5998. (*Mr. Harrison.*) It would appear, would it not, in Dr. Frankland's monthly reports?—Yes, it has been printed over and over again.

5999. (*Chairman.*) I understand you to say that you supply about 34 gallons per head per diem, taking the whole of the population, including the trade purposes, and you take off about eight gallons for the trade supply. How long do you imagine that the gross quantity that you now supply will be sufficient for the population?—We have the power of taking to the extent of 20,000,000 gallons a day, and we take rather more than 8,000,000 gallons, so that there is a margin of nearly 12,000,000 gallons within our parliamentary limit, or within the arrangement that we have made with the Thames Conservancy for taking a certain quantity daily.

6000. Have you the means of coming to any conclusion as to when it will be necessary for you to increase your supply beyond what you now furnish?—There is an increasing quantity every year. We find that as we increase our number of tenants so the quantity of water increases. I think that people use more water now than they used to do some two or three years back, for baths and other purposes, and for boilers at the back of kitchen stoves, and a variety of things which are now introduced into houses which were never thought of a few years ago.

6001. Is the population increasing in that district?—Yes, very rapidly.

6002. How long do you think your parliamentary powers will be sufficient; have you the means of arriving at any conclusion upon that point?—I should think that they would be sufficient for the next 50 or 100 years, but it is impossible to say. We are only taking now 8,000,000 gallons out of 20,000,000.

6003. (*Sir J. Thwaites.*) Is that the margin of reserve in respect of the Grand Junction Company, out of the 50,000,000 gallons that have not been utilized?—Yes, each company has the power of taking 20,000,000 gallons, that is, the Southwark, the Grand Junction, the West Middlesex, the Chelsea, and the Lambeth companies.

6004. That is to say, those five companies are taking now 50,000,000 gallons, and they have statutory power to take to the extent of 100,000,000?—Yes, so that we are taking something less than one half of our statutory power.

6005. (*Chairman.*) Supposing that you wanted a greater quantity than that, is it your opinion that the basin of the Thames would be able to supply it?—I think there is no doubt of that. The lowest gauging that has ever been taken of the Thames has amounted to 360,000,000 gallons in 24 hours. The average is something like 600,000,000, and in time of flood it is more than 50 times that quantity.

6006. Where has this gauge to which you refer been taken?—It has been taken at Teddington lock.

6007. (*Sir J. Thwaites.*) Have you the mean gauge?—No, I have not. The average I should say would be something like 600,000,000 gallons a day.

6008. (*Chairman.*) Supposing it were necessary to increase the supply, you say that the Thames basin would be able in your opinion to supply it; in what manner would you collect it?—If it were necessary, large storage reservoirs might be provided in the upper Thames; but as we only take now one-seventh of the minimum flow, it would be a long time before anything of that kind would be required.

6009. And the quality of the water you say is good?—It is very good indeed for all purposes, not only for domestic purposes but for manufacturing purposes. Brewers and tanners, and those people who use large quantities of water for trade, all prefer the Thames water to any other water that they can get.

6010. What other water could they get?—Well water from artesian wells and rain water. They come to the companies now even for water for condensing purposes for engines.

6011. As the engineer to those companies, have you turned your attention at all to the system of constant supply at high pressure?—There is a clause in the Act of 1852 making it compulsory on the water companies to give a constant supply if certain things are carried out by the inhabitants.

6012. Are those certain things being carried out?—I do not think there is any change in that respect being carried out.

6013. What are the things that are required to be done by the inhabitants?—Putting all their house fittings in such order as to prevent the waste of the water, and that would involve such an extraordinary amount of outlay, particularly in the poorer districts, that I do not think there is any probability of the public ever doing anything of the kind to carry it out.

6014. Do you think that it would be a good thing?—I think that in the poorer districts it might be an advantage, but I think that practically the better class houses have the best constant supply that they can have by having a good cistern in their houses, by means of which, in the event of any interruption from the breaking of a main, or a conflagration in the neighbourhood, or anything of that kind, they have a supply of water which will last them two or three days in their own cisterns; whereas if they merely depended upon a pipe passing into the house, the moment that there was any interruption to the flow in the main they would be deprived of that accommodation.

6015. Then are we to infer that you are not in favour of the constant supply system?—I think that it has its evils. Perhaps in a poorer neighbourhood it might be an advantage, but I think where cisterns are properly taken care of and cleansed, and so on, that is the best constant supply that anyone can have. In fact, I do not know how the constant supply is to be arranged in a house, where the kitchen boilers, for instance, require constant filling; and with regard to waterclosets, again, it would be an exceedingly inconvenient thing to have water absent from the house probably for 24 hours in the case of an accident to a main, or anything of that kind.

6016. (*Sir B. Phillips.*) Are the accidents to the mains of which you speak frequent?—The large valves want repairing occasionally, and the mains will break now and then, and alterations are necessary, such as putting on new branches to a main, and when the main has to be cut out and a connexion made to it to go down a side street during the whole of that time, which may occupy several hours, if there were no storage the people would be deprived of water.*

6017. (*Chairman.*) Could you not have both the constant supply and the storage system also?—I do not think there would be any advantage in the constant supply, because virtually it is a constant supply now if they have proper cisterns.

6018. (*Sir B. Phillips.*) Then there is at present a form of constant supply to the better-class houses?—It is so where there is a good cistern in the house, the cisterns being filled every day; if they hold anything like 200 or 300 gallons, or whatever it may be that is necessary for the use of the house, they have it at hand.

* See statement at end of evidence.

J. Quick, Esq.
26 Feb. 1868.

6019. (*Chairman.*) When cisterns are put to houses I presume it is with a view to their containing at least 24 hours' consumption?—We always advise them to put cisterns for 48 hours' consumption, and in most of the better-class houses they even go very much beyond that.

6020. That would be then, as you say, practically a constant supply?—That is a constant supply, practically; and we now, both the Grand Junction Company and the Southwark and Vauxhall companies, give a Sunday supply, in addition to the ordinary week-day supplies, in several of the poorer districts, so as to endeavour to meet the requirements of the public in every way that we can.

6021. Then if the cistern system, which in point of fact is a constant supply, is the one which your company recommends to the better-class houses, giving them two or three days' consumption, and you think that the other system of constant supply would be an advantage in the poorer districts, you are in favour, are you not, of a constant supply in London?—I think it would be an advantage to the poorer districts; but it would be accompanied by an enormous amount of outlay to accomplish it.

6022. In what way would that outlay be rendered necessary?—From the present state of the house fittings in the poorer districts; if any more pressure were put upon the pipes, and taps, and valves, and things of that kind, they would all fly to pieces; the pipeage is weak, and the taps are imperfect, where there are taps, and if they were not put in proper order the waste would be so great that there would not be any pressure at all; the water would all run down the drains, and in the higher portions of the district they would never see any water at all.

6023. Do you think the expense of putting them in proper repair would prevent its being carried out?—We find great difficulty in getting the owners of small property to lay out a single sixpence for benefitting their tenants in any way, and I am quite sure that any representation that the companies could make would never induce them to do it unless there were some legislative power to compel them.

6024. Does your company supply one sort of water to all consumers, trade and streets and private individuals?—Yes, it is all filtered exactly in the same way and pumped from the same source. There is not any difference at all; it passes through the same trunk mains, and is divided out into the various pipes.

6025. Would there be any advantage in your having two sorts of water?—It would involve a double system of pipeage, which would be attended with enormous expense. The company now have 360 miles of pipe in constant operation.

6026. (*Col. Harness.*) Do you deliver any water through meter?—To some of the trades we do, but not for general consumption; it is found too expensive an operation for small purposes, that is say, for ordinary house supplies.

6027. (*Sir J. Thwaites.*) When you speak of constant supply is it not admitted that in the case of houses of a certain class, with closed boilers for example, for supplying baths and for other purposes, you must, under any system, have a cistern for the purpose of preserving sufficient water to keep in action those arrangements?—Yes, under any system.

6028. I apprehend that the number of houses of that class, as compared with the number of houses in the metropolis, would be very small, would it not?—Not in the Grand Junction district; in the whole of the new portions of the Grand Junction district they have appliances of that kind in their houses; in fact, I should think in two-thirds of the houses. They supply a district from the east side of the Haymarket, the north side of Pall Mall, in a straight line up to Oxford Street, taking in all the great squares, and up as far nearly as Kilburn Gate in the Edgware Road, and then westward again, so that they take in a very fine district—one of the best districts in London as far as property is concerned.

6029. Has your attention been directed to the principle of a constant supply in regard to its effect upon the public health?—I think, as I have stated before, that in the poorer districts there would be a great advantage from the constant supply, but in the better class of property I cannot conceive that there would be any advantage at all in respect of health.

6030. Do not you think that the principle of storing water in cisterns, whether well or ill constructed, has any effect upon the health of the inhabitants?—I do not.

6031. A constant supply would have its advantages for the purposes of fire, would it not?—I think there is a great question whether it would or not.

6032. I mean under proper pressure?—That is the difficulty. If there are so many thousands of taps in connexion with the mains, there will be always a certain amount of draught passing into the district which will lower the pressure. At the present time the whole of the trunk mains or principal mains of the district are kept under the full pressure all night, and in case of fire they have only to open one of the side cocks and direct the water to the particular place where the fire may be burning, and all the pressure can be directed by merely opening these one or two cocks, whichever it may be.

6033. But I wish you to direct your attention not to such a pressure as that the fires might be extinguished from the hydrants by application of the hose, but to such a pressure as would keep the pipes charged and the supply sufficiently full to be pumped by means of a separate fire engine.—That can always be done by the mere opening of one of the side cocks leading from the trunk main.

6034. The difficulty now is to find water, is it not, in case of a fire?—The water is always in the main.

6035. A recent case occurred where water was not to be obtained in any quantity for useful purposes for more than 20 minutes after the fire, and the destruction was pretty well completed, how do you account for that?—I think that that arises principally from the a want of understanding between the brigade and the water companies.

6036. It arose from the fact of there being no water in the main, and would not the constant supply under an ordinary pressure (I am not speaking of high pressure) have prevented that state of things?—Yes, if the water had been in the main but it might have happened that the main was severed at the time by some repair or some alteration, but I do not know the circumstances.

6037. There was no repair or anything of that kind?—Then I cannot conceive how it could have been; but if there were a proper arrangement that when a fire is reported at the fire station they should despatch a man to the turncock of the district, in 99 cases of 100 the water would be at the fire before the engines arrived, but unfortunately the brigade will not take the responsibility of calling the turncock, and we cannot bring about any arrangement of that kind; we pay any amount of rewards, or anything of that kind, but it is of no use, they will not do it.

6038. Without discussing that question, I would just confine your attention to the question of constant supply, as compared with the present intermittent system; would not a constant supply as a general rule give greater facility for the suppression of fire than the system now prevailing?—There is no doubt that if the water were always in the services it would be so, but the water now is in the whole of the trunk mains of the company, and the services are merely shut off by the closing of a side cock after the general service of the day, whatever it may be, is over. If it is on from 12 to 3, or whatever time it may be, the cock is then shut down, the trunk main having the full pressure during the whole of the night or the remaining portion of the 24 hours.

6039. Then it is shut off, according to your own acknowledgment, from the mains that would be used for the purpose of supplying water for suppressing fires?—The whole of the side services are shut off.

6040. What would you say if it frequently occurred

that the turncock could not be obtained in less than 20 minutes from the time that the fire had been discovered?—If it is necessary to obviate that in any way, we undertake to furnish any amount of tools to the fire brigade, to teach them the position of all the cocks in the district, and to give them any amount of information that we can, and I think that we can ensure a full pressure into any side service by the present means; whereas if the water were left all over the district, in the place of having a head of 50 or 60 feet, which we may get now in a very few minutes, it might be reduced perhaps to 10 or 15 feet.

6041. Would not the very simple process of filling all the pipes be very much better than the present complicated system, liable to delay as it is in working?—If you could do away with the waste from the lead pipes leading into the houses, there would be no difficulty in leaving the whole district open.

6042. My question has reference now not to high pressure, but to a sufficient pressure to fill the service pipes. — Practically that would interfere so much with the general working of the district, that we should not get any water at all into the cistern in certain portions of the high districts if we were to allow all those side services to be open.

6043. (*Chairman.*) How is the water that is consumed at fires paid for?—It is not paid for at all, the companies afford it gratuitously.

6044. (*Sir J. Thwaites.*) You have spoken of a clause in the Act of Parliament which gives the right to the inhabitants to demand a constant supply on certain conditions; that is to say, certain things must be done by the inhabitants to give them a *locus standi* to call upon the companies to supply under constant pressure; is it not generally understood that that clause was arranged with the water companies, they professing on the one hand to give that right to the public, but the complication of conditions was such as to render it utterly nugatory?—The companies have never objected, and would never object to give the constant supply if the public would fulfil the obligations of that clause.

6045. Are not the obligations of such a character, and the parties to determine the merits of the application so interested in the supply of water, that it is utterly impossible to put that clause into action?—I cannot conceive that it is utterly impossible to put it into action, it is merely this, that every one is to put his pipes and taps into such order as to prevent waste.

6046. Are not the water companies made the judge of that?—The requisition must be from four-fifths of the tenants or owners of houses on a district main, and certainly the companies are left to judge whether the pipes are in proper order or not.

6047. Are not the arrangements of such a character that they must be approved of by the water companies, and that four-fifths of the occupiers or owners, or whatever the proportion may be, shall comply with those conditions?—Yes, that is so.

6048. Then if the water companies were to allege that the parties had not sufficiently carried out their obligation in strengthening their pipes and arranging the apparatus generally, the water companies could still refuse to supply on the constant system?—I think that there is an appeal to two magistrates or to the Board of Trade to decide what the proper fittings are.

6049. What is the clause by which you say a constant supply is compulsory upon the company upon certain things being undertaken by the owners of the houses?—The 15th and 16th Victoria, chapter 84, section 15: "After the expiration of five years from "the passing of this Act every company shall, subject to the provisions of the special Act relating to "such company, provide and keep in the district "mains already laid down, or hereafter to be laid down by them, a constant supply of pure wholesome water sufficient for the domestic use of the inhabitants of all houses supplied by such company, at such pressure as will make the water reach the "top storey of the highest of such houses, but not "exceeding the level prescribed by the special Act of "such company; provided that no company shall be "bound to provide a constant supply of water to any "district main until four-fifths of the owners or "occupiers of the houses on such main shall by "writing under their hands have required such company to provide such supply, nor even upon such "requisition, in case it can be shown by any company "objecting to the same that more than one-fifth of the "houses on such main are not supplied with pipes, "cocks, cisterns, machinery, and arrangements of all "kinds for the reception and distribution of water, "constructed according to the regulations prescribed "by the special Act or by this Act, or which any "company with the approval of the Board of Trade "may from time to time make in that behalf."

6050. (*Chairman.*) Four-fifths of the tenants or owners in the district are required to put their fittings into proper order to take the constant service, and then having done so, you would be required, would you not, to supply them in the manner required by the Act?—Yes.

6051. (*Sir B. Phillips.*) Would that be a very expensive process?—It would be a very expensive process to the owners of property.

6052. Have you any idea what it would cost per house?—It depends upon the class of house, in some cases it might cost 2*l.* or 3*l.*, and in others 10*l.* or 15*l.* per house.

6053. It would depend, would it not, upon the size of the house and the quantity of water required in it?—Yes, and the position of the supplies in the house.

6054. (*Sir J. Thwaites.*) Is it not quite as I have put it, that after the part of the clause pointing out how many inhabitants must agree and subject to the final approval of the Board of Trade: "It shall be "lawful for the surveyor or any other person acting "under the authority of the company, between the "hours of 9 of the clock in the forenoon and 4 of the "clock in the afternoon, to enter into any house or "houses on such district main in order to ascertain "whether the pipes, cocks, cisterns, and machinery "of such house and houses are so constructed as aforesaid; and provided also that any company may "with the consent of the Board of Trade suspend the "giving of such constant supply." So that you are really made the judge as to whether the alterations required by the Act are satisfactory or not to the company; therefore, if you who are made the judges were disinclined to carry out this arrangement, might you not urge such objections as should make this professed advantage on behalf of the public a nullity?—I do not think that there is the slightest disposition on the part of the companies to do so. I am sure that the companies would be very glad to comply with the requirements of that clause, if the public would do their part to prevent the waste of water.

6055. (*Col. Harness.*) How do you define a district main; it might be small or large, might it not?—It is a very difficult question to answer, but I look upon a district main as a main branch that the turncock may command by one stop cock. It may have many ramifications, but they would be commanded by that one stop cock.

6056. And a very large population may depend upon it?—That may be so.

6057. (*Mr. Harrison.*) Can you state to the Commission without any difficulty what would be the cost of raising say 1,000 gallons or 1,000,000 gallons 100 feet high?—In the case that I have just been mentioning the water is pumped three times over. It is pumped first at Hampton to an elevation of 94 feet, then it is pumped at Kew to an elevation of 200 feet, and then at Campden Hill to 150 feet; so that to raise it 100 feet is only part of the expense to the company.

6058. You do not know what the expense of the first rise is, the raising in to Camden Hill?—I do not know that at present, but I can furnish the Commission with it no doubt. (*See Appendix K.*)

J. Quick, Esq.
26 Feb. 1868.

6059. Have you found that the quantity consumed per head has been going on by any regular 'progressive increase for many years?—It has been going on gradually increasing from year to year, and still goes on.

6060. Looking forward to a few years hence, what is your view of the probable quantity per head that you ought to calculate upon?—We find that by employing one or two inspectors to go round the district, and to check the waste as far as we can without causing any distress to the tenants, we can reduce the quantity even that we are pumping now, therefore I do not think that for some considerable time to come there will be any very great increase; because if the companies will only go to the expense of putting on some few extra men to check the waste by calling upon people to put their taps, and so on, in a proper state of repair, the quantity now pumped ought to be very much reduced.

6061. In making an estimate in such a case as that which we are now considering, what, from your experience, should you say would be a safe quantity per head to calculate upon?—I should think 30 gallons per head would be the very outside that there ought to be supplied, and that is about the quantity now given to the whole metropolitan area. It is as near as possible 29¾ or roundly 30 gallons per head.

6062. Is not the greater portion of the district that you supply occupied by the better class of population?—Yes, in the Grand Junction district it is so.

6063. Do you find there that the consumption per head is much larger than in the poorer districts?—Yes, very much larger, and that arises from the conveniences that people have in the better-class houses, namely, boilers, baths, and water-closets, and matters of that kind.

6064. You supply the water in Westbourne Terrace, do you not?—Yes, we do.

6065. Have you found within the last month or two that there has been a complaint of the colour of the water?—Yes, during the heavy floods, the water was perfectly bright, but there was a strong colour in it.

6066. Was that merely arising from the floods?—Yes, it was merely arising from the floods, the washings of the clay from the Oxfordshire hills generally imparts a certain amount of colour to the water.

6067. At the present moment that colour is nearly gone, is it not?—I think it is quite gone; it has been gradually getting better from day to day.

6068. That is not a usual occurrence with your water, is it?—No; sometimes we do not see anything of the kind for three or four years, but it has been more tinged during the past month than I have ever seen it before.

6069. (*Sir J. Thwaites.*) Is that after filtration?—Yes, it is after filtration. It is the colour which filtration will not take out; it is a stain in the water. The water is perfectly bright and pellucid, but it has a decided tinge of yellow in it.

6070. (*Mr. Harrison.*) In the present system of supply, is it not one of the great objections to the cistern system that those cisterns are not kept clean by the owners of the houses themselves?—That is so.

6071. And if they got the water direct from the pipes, they would get it, would they not, in a purer condition?—There is no doubt of that.

6072. Your view perhaps would be that it would be a necessary thing to have a combination of cisterns and a supply direct from the pipes in the same house?—Yes.

6073. Up to the present time the practical effect of the clauses in that Act of Parliament has been, has it not, that no company has been called upon by the inhabitants to give them a constant supply?—That is so.

6074. Do you think that the water companies themselves would object to it if they were called upon by the inhabitants, and if the inhabitants were to do their part of the duty?—I do not think they would. Of course the water companies would have to lay out a very large sum of money to enable them to do it, and I had perhaps better explain why that would be so. It is on account of the undulations in the districts. In the Grand Junction district there is some portion of it but little above the level of the Thames, whereas other portions are nearly 200 feet above the level of the Thames, and it is constantly rising and falling; and of course if the water is allowed to run to waste in any way in the lower portions of the district, unless there is a division of the trunk mains the high portions would never get any water at all.

6075. Still there would not be an objection on the part of the companies to that outlay?—I think not, if proper provisions were made.

6076. And it would necessarily be attended with much greater stringency of supervision on the part of the water companies?—Yes.

6077. Do not you think that the result would be great economy in the consumption of water per head?—There might be an economy in the quantity of water pumped, but the difference of cost to the companies would not be any very great deal. You would not reduce the expense of management, or labour, or anything of that kind; it would be the mere expense of pumping.

6078. Still there would be economy in the actual consumption per head?—Yes; there is no doubt there would be less water used, supposing that all the fittings were put in a proper state to prevent waste.

6079. You have been connected with the water companies of London from almost the earliest time, have you not?—I have been connected with them a long time.

6080. (*Col. Harness.*) What part of your district is dependent entirely for a high-level supply on that lofty stand pipe of which you have spoken?—The whole of the district north of the Uxbridge Road, up as far as Kilburn Gate.

6081. Then I presume in that district the pressure in your mains is maintained by keeping the stand pipe full?—Yes, by keeping the stand pipe full, and always pumping the water up to that level.

6082. Have you your engines going at night?—Yes.

6083. (*Mr. Prestwich.*) What do you estimate to be the waste under the present system of supply?—I should think nearly one-third of the quantity pumped.

6084. That is to say, out of 34 gallons per head you would estimate that 11 or 12 gallons are lost?—Yes.

6085. (*Sir J. Thwaites.*) I understood you to state, in answer to his grace's question, that the average supply would be 34 gallons per head per diem, but that the actual supply finding its way to a house for domestic purposes would be about 26 gallons; is not that so?—Yes.

6086. That is reducing it by eight gallons?—Yes.

6087. Am I to understand that the waste out of 34 gallons is 12 gallons?—Yes, I have no doubt of it.

6088. Then you are taking away 12 gallons and eight gallons from 34 gallons, leaving 14 gallons for domestic purposes?—34 gallons is the entire quantity of water pumped by the company, and distributed to a certain number of inhabitants.

6089. Thirty-four gallons per head is the gross quantity pumped, and you say that then out of that 34 gallons the waste is 12 gallons; then for street and trade purposes you have another 8 gallons, that is 20 gallons subtracted from 34, leaving for domestic purposes 14 gallons per head only?—Yes, 14 or 15 gallons. I have no doubt that is the quantity; and if you take the consumption in some of the large northern towns of 21 or 22 gallons, including trade purposes, it comes to about the same thing.

6090. That is to say, if you have any other supply than the supplying of private houses, 14 gallons per head, if you could deliver that quantity, would be ample for all purposes?—Yes, I should say 14 or 15 gallons without waste would be ample.

6091. (*Chairman.*) Now you have 14 or 15 with waste?—It is 14 plus the waste.

6092. (*Sir J. Thwaites.*) Have you any idea, or

J. Quick, Esq.
26 Feb. 1868.

does your experience confirm that view of the case that a constant supply would be a saving of water?—No, it all depends upon the amount of supervision, because unless people are very careful indeed in not allowing the taps to leak or the water to run to waste, the supply might be very much in excess of what it is now with all the waste.

6093. Supposing that there were an ordinary amount of inspection by the companies to see that the arrangements are such as not to admit of waste, would not the principle of constant supply result in a saving of water, and prevent the waste which now occurs by persons tying up the balls and permitting the water to run during the whole time that it is on in the main?—I think that is the great question. If everything was put in the most perfect order that it could be, there is no doubt there would be a considerable saving beyond the present quantity pumped; but it all depends upon the amount of supervision and the more or less perfect state in which the fittings are maintained.

The witness withdrew.

The witness subsequently sent in the following statement to illustrate his answer to question 6016. He adds "In nearly all these cases it was found "necessary to keep the stopcock on the main or "service pipe short during the carrying on of the "work, for periods varying from 1 to 24 hours."

SOUTHWARK AND VAUXHALL WATER COMPANY.

A DETAILED ABSTRACT showing the Number and Nature of the different Works performed in this Company's District during the 12 Months ending 31st December 1866, which would have occasioned Interruptions in the Supply of Water to the Tenants, supposing such Supply had been constant instead of intermittent.

1866.	Packing or fitting new Spindles to Side Services.								Setting up Leaky Joints on Main and Service Pipes.			Lead Pipes repaired on Services and Mains.	Mains cut into for connecting to Side Services.	New Supplies laid on.	Accidents to Trunk Mains.	Remarks.
	3″, 4″, 5″, and 6″ Cocks.		7″, 8″, and 9″ Cocks.		10″ and 12″ Cocks.		20″ and 24″ Cocks.									
	Packed.	New Spindles.	Packed.	New Spindles.	Packed.	New Spindles.	Packed.	New Spindles.	3″ to 6″	7″	9″ to 36″					
January -	25	4	9	2	2	—	—	—	106	2	6	36	9	111	—	
February -	20	10	31	7	3	1	—	—	82	7	12	62	12	119	1	
March -	38	8	16	5	1	—	—	1	107	8	11	64	4	123	1	
April -	46	9	14	—	1	1	1	—	101	6	2	44	11	126	—	
May -	24	5	9	2	1	2	—	—	75	9	15	51	14	134	1	
June -	66	16	10	—	—	2	—	—	54	2	8	44	5	162	—	
July -	37	6	9	—	4	1	—	—	86	5	8	27	12	171	1	
August -	46	14	16	5	—	3	—	—	88	10	2	45	6	156	1	
September	38	8	2	—	5	2	—	—	52	4	5	31	4	152	—	
October -	55	3	12	5	—	1	1	—	88	8	4	47	16	149	—	
November	38	—	21	—	1	2	1	—	80	5	8	80	9	135	—	
December	9	2	12	—	—	—	—	—	91	1	6	68	7	124	—	
Totals -	442	85	161	26	18	15	3	1	1,010	67	87	599	109	1,662	5	4,300

WILLIAM RICHARD MORRIS, Esq., examined.

W. R. Morris, Esq.

6094. (*Chairman.*) What metropolitan water-company do you represent?—The Kent Waterworks Company.

6095. In what relation do you stand to that company?—I am the engineer.

6096. Can you state the area that the Kent Waterworks Company supply?—I cannot; I am not prepared with it at this moment. We have made some very large additions within a very short period, and I do not know the total quantity of area. I know the total number of houses.

6097. Can you describe the district?—The district extends from Camberwell to Dartford in one direction and from the river Thames to Chislehurst and Bromley in the other.

6098. But you cannot give us the area?—I have not calculated out the quantity. A portion of this district is very new to us now, and I am not prepared to say what the exact area is.

6099. From whence do you draw your supply?—The whole of our supply is from deep wells in the chalk at various points. We have wells at Deptford, at Charlton, at Plumstead, at Crayford, and at Bromley.

6100. Is the Ravensbourne in your district?—Yes, the Ravensbourne is a small river which formerly fed our works.

6101. Do you mean that you have ceased to take water from the river Ravensbourne?—Yes, we have abandoned the Ravensbourne, and we pump wholly from artesian wells.

6102. How long is it since you have gone to artesian wells for a supply?—During the last six years our supply has been entirely from artesian wells.

6103. What was the cause of your giving up the Ravensbourne and taking to those wells?—I believe the principal cause was that we had exhausted the contents of the river. The flow of the river was completely absorbed by our works, and we were necessitated to find other water. We were guided in that respect by the recommendation of a former commission upon this subject, who strongly recommended chalk water.

6104. What is the quality of the water?—The quality as compared with the well water of the district is soft; as compared with rain water it certainly is hard. It is rather harder than the Thames water.

6105. You have mentioned that you went to deep wells for your supply in consequence of the report of a commission. To what commission do you refer?—The commission that I speak of was in 1851, and was composed of Professors Graham, Miller, and Hoffman.

6106. I see by a return that your water is of the hardness of 27·3 degrees, as compared with the river Lea 18·2?—Probably it is so.

6107. And the sewage contamination of yours is ·4220 as against the river Lea ·2950?—I totally deny that as a fact, and I do not believe that any other person but Professor Frankland would venture to assert it. Indeed, Professor Frankland himself seems to have various opinions upon the subject from time to time. When Professor Frankland has reported the Lea as containing no previous sewage at all in it last August, and the deep wells at Grays as containing $8\frac{1}{2}$ per cent., there must be some misunderstanding as to the terms.

6108. Have you any analysis of your own water?—I have not an analysis of the whole of the wells, but on the subject of sewage contamination I beg leave to hand in this statement of Dr. Letheby:—

W. R. Morris, Esq.

26 Feb. 1868.

LETTER addressed to the Directors of the Kent Water-Works Company by Dr. Letheby, Professor of Chemistry, &c. &c.

In the weekly Report of the Registrar General for the week ending Saturday, May 4th, there is a statement to the effect that "The Kent water is altogether the worst sample of the eight," that is, of the water supplied by the eight water companies of London; and this opinion is founded on the Report of Dr. Frankland, which, under the head of previous sewage contamination (estimated), gives 3195 parts of sewage in 100,000 parts of water, which is a little more than 3 per cent.

Having made very careful analyses of the Kent water, month by month, for the last three years, and having failed to discover, at any time, the least trace of what can be termed sewage contamination, and having, moreover, made two analyses of the Kent water in the very month to which the Registrar General's remarks apply, I was surprised to find it stated that the Kent water was, in all respects, the worst kind of water supplied to the metropolis.

So far is this from the case, that every month for the last two years I have reported to the Association of Medical Officers of Health of London, that the amount of organic matter contained in the Kent water is so insignificant as to be hardly discoverable by the most refined processes of chemical research; when, for example, the water is examined in a long glass tube, it is found to be as blue and free from organic tint as distilled water; and when it is tested by means of an oxydising agent (permanganate of potash), the amount of oxygen required to oxydise everything in it of an oxydisable nature, does not amount to the one-hundredth part of a grain per gallon of water: in fact, the average amount of organic matter in the Kent water for the last twelve months does not exceed the tenth of a grain per gallon, or one part of organic matter in 700,000 parts of water; and during the very month referred to in the Registrar General's Report, the quantity of organic matter in the sample which my assistant took from a main pipe at New Cross was so small as not to be capable of estimation.

How then are these discrepancies of opinion regarding the quality of the Kent water to be reconciled? This is easily done by considering that the expression used by Dr. Frankland, as regards a supposed previous sewage contamination, is but a figure of speech; and however alarming it may be to those who have no knowledge of its true signification, it really means no more than that at some time in the world's history, perhaps in an antediluvian period, a hypothetical quantity of organic matter had been deposited; and that in subsequent time the water, while percolating and slowly finding its way through the fine fissures of the chalk, had dissolved the animal matter, which had then undergone such a thorough change by oxydation as to leave its mark in a scarcely discoverable amount of combined and harmless nitrogen. The change indeed of this so-called previous sewage contamination is as complete and as salutary as that which occurs within the growing plant in the transformation of manure into food: and it would be just as true and as pertinent to say that the nitrogen in the bread which we eat represents a certain amount of sewage contamination. Unfortunately, these exaggerated views of the pure chemist, when contemplating the facts of pathological or physiological science, are apt not merely to alarm unnecessarily the public mind, but they offer serious impediments to the progress of sanitary knowledge, and also weaken the confidence of the public in the usefulness of protective medicine.

Let me then, in conclusion, give you the most positive assurance that the water supplied to the public by the Kent Waterworks Company is not only free from sewage contamination, but is in all respects a good and wholesome water: so little indeed is it tainted with organic matter, that it offers in this respect a striking contrast to the highly-praised soft waters of Cumberland and Wales.

(Signed)
HY. LETHEBY, M.B., M.A., Ph.D., &c. &c.,
Professor of Chemistry in the College of the London Hospital and Medical Officer of Health for the City of London.
17, Sussex Place, Regent's Park,
18th May 1867.

And again on the subject of the well at Bromley on the same point there is another very recent report which I will hand in.

REPORT of an Examination of Water from the Wells at Shortlands, one of the Pumping Stations of the Kent Waterworks Company.

On Thursday, the 9th instant, I visited Shortlands with Mr. Morris, the engineer of the company, and took samples of water from the *deep well* which supplies the works, and also from a disused *bore-hole*, which receives surface water.

I observed that the water from the deep well was pumped from a great depth through an iron cylinder, which had no communication with the surrounding surface water that stood at a much higher level in the outer cylinder, and which was wholly unaffected by the pumping operation. Mr. Morris informed me that the cylinder through which the water was pumped was perfectly water-tight, and that it passed through 60 feet of clean fine sand and 10 feet of marl into the chalk, the well being carried to a further depth of 180 feet into pure white chalk, thus making a total depth of 250 feet from which the water is supplied.

The character of the district in which the well is situated is open and free from habitations; in fact, there were no apparent sources of pollution for even the surface water; not only is there a considerable distance between Bromley and Shortlands, made up of materials which are notoriously powerful as purifiers of water, but there is also an impervious layer of clay, 10 ft. in thickness, between those strata and the chalk, through which the surface water cannot pass. As, however, I considered it desirable to ascertain the quality of the surface water, as well as that of the deep well, I requested to be furnished with water from the bore-hole, which is only a short distance from the well, and which is open to surface percolation. In this manner I obtained, under my own immediate observation, samples of water from the deep well and from the bore-hole.

Both of these samples were perfectly bright and colourless even when examined in large volume, as in a glass tube two feet in length. They were also cool, sparkling, and agreeable to the taste.

On being analysed for ammonia with the view of ascertaining if they contained a trace of decomposing organic matter, it was found in each case that the proportion of ammonia amounted to only 0·0036 of a grain per gallon, of one part in nearly 19,500,000 parts of water, and the minute proportions of organic matter in the water yielded, in one case, only one part of ammonia in 50,000,000 parts or water, and in the other, one part in about 27,000,000 parts.

Tested in another way, it was found that the organic matter required only 0·05 of a grain of oxygen per gallon for the deep-well water, and 0·1 for the bore-hole water.

The mineral constituents of the two samples were very nearly alike, and were as follows:—

	Deep well water. grains.	Bore-hole water. grains.
Carbonate of lime and magnesia	14·85	15·75
Sulphate of lime	2·13	2·52
Alkaline chloride (common salt)	0·90	0·90
Nitrate of lime	1·86	0·80
Silica and alumina	0·53	0·73
Total per gallon	20·27	20·70
Hardness	17·0°	17·0°
Ditto after boiling a quarter of an hour	3·5°	4·0°

Lastly, experiments were made for the purpose of ascertaining if the water acted on lead, and the results were negative and therefore satisfactory.

The conclusion from these investigations is, that the water derived from the deep well at Shortlands is good and wholesome; that it is not only remarkably free from organic impurity, but is also less than usually charged (considering it is chalk water) with saline matter; and I have no hesitation in saying that it is in all respects a good and wholesome water, and fit for domestic purposes.

I am also equally satisfied with the results of the examination of the water from the bore-hole, for although it is, in all probability, largely charged with surface water, yet it does not exhibit a single property that renders it all unsafe for domestic use; and even if it were so, its quality would in no way affect the water derived from the deep well.

(Signed) HY. LETHEBY, M.B., M.A., Ph.D., &c.
Professor of Chemistry in the College of the London Hospital, and Medical Officer of Health and Chemical Analyst of the City of London.
College Laboratory, London Hospital,
January 30, 1868.

To the Directors of the Kent Waterworks Company.

I have also made a report of my own upon the same subject, making three reports on the point, and it is as follows:—

COPY of a LETTER addressed to the Bromley Local Board of Health by the Engineer to the Kent Waterworks Company.

Kent Waterworks,
SIR, February 10th, 1868.

I ENCLOSE copies of Dr. Letheby's Report on his special examination of the water supplied to Bromley from this company's works at Shortlands.

The accuracy of modern chemical analyses leaves little

room for difference in the determination of the mineral and other constituent parts of water, and a comparison of Dr. Letheby's examination with that of Dr. Frankland, as reported by the Registrar General, will show that this is not so much a question of analysis as upon the accuracy of the comment and the truth of the deductions.

Following the figures from the Registrar General's Report indicating the amount of "previous sewage contamination" in water from the Kent Waterworks Company's wells at Deptford and Shortlands, and from the South Essex Company's wells in the chalk at Grays, we find it alleged that in each of these cases the waters have a far greater proportion of sewage than the Thames. The figures presume that every 100 gallons of water from Shortlands well has a mixture of 4¾ gallons of London sewage, or its equivalent; and as the chalk rock at Shortlands would yield a supply quite equal to that of the company's wells at Deptford (5,000,000 of gallons daily), it would follow, that on using the Shortlands water to its fullest extent it would be equivalent to pumping therefrom 240,000 gallons of sewage in its most offensive sense. There is no avoiding this absurd conclusion on Dr. Frankland's assumption: this taint of sewage on this hypothesis extends to every spring that issues from the chalk in the county, and to every town deriving its supply of water from the chalk formation. The explanation of this mere figure of speech, "previous sewage contamination," will be found in Dr. Letheby's Report on the subject, which I enclose.

The Government Commission of 1851 of Professors Graham, Hofmann, and Miller, recommended in the most earnest manner the chalk as a source for future London water supply.

Dr. R. D. Thompson, the predecessor of Dr. Frankland, in his Cholera Report of 1856 urged that this water is not subject to contamination by organic matter; and even if rain water, the primary source of this aqueous deposit, should convey any matter from the surface, the chalk would oxydize the organic matters and convert them into new and inert forms.

The Board of Trade in 1860, through Captain Galton, who examined the Kent Company's water supply, assisted by Professors Abel and Miller, urged the completion of the scheme of supply from the chalk then in progress by the company.

Finally, during the last session, a committee of the House of Commons inquired into the London water supply: the Metropolitan Board of Works attended and represented the public, but no objection was taken to the purity of the Kent Company's water, on which the Committee made a favourable report.

The well at Shortlands is sunk to a depth of 340 ft. below the ground on which Bromley stands; it is formed with double iron cylinders, the outer cylinder enters the chalk at the depth of 70 ft. (160 ft. below Bromley), the inner cylinder is continued considerably deeper, and is bedded firmly in the chalk: to ensure sound work the lower portion of the work was executed by divers under 60 ft. of water; the test of the perfection of this work is the difference of level that exists between the two cylinders when the engine is pumping, the level of the outer cylinder water remaining unchanged while the water sinks under the operation of the pump in the inner cylinder. This care was taken to exclude effectually the surface water, though from Dr. Letheby's analysis the surface-water itself does not appear to possess any injurious quality.

I place these facts in opposition to Dr. Frankland's theory, and I regret that that gentleman has not personally inspected the works, or even assured himself that the samples of water obtained for analysis were collected with due precaution to ensure purity. I think such a visit would have spared me this explanation, and the public would not have been needlessly alarmed.

I shall be happy to attend at any time your Board may wish and give any further information on this subject they may require.

I am, sir, your obedient servant,

W. R. Morris,

Engineer to the Kent Waterworks Company.

To R. Latter, Esq.,

Clerk to the Local Board of Health, Bromley.

6109. (*Sir J. Thwaites.*) When you say that Dr. Frankland is the only person who would venture to make such a statement as that which you have given us, namely, as to the degree of hardness and the degree of impurity, do you suppose that Dr. Frankland has any special prejudice against the Kent Company?—I think you misunderstand my words. My words apply only to the previous sewage contamination. The previous sewage contamination by Dr. Frankland is estimated upon the amount of nitrates in the water. I say that all other chemists tell you that the nitrates have other origin than sewage, and as applied to chalk it is not only in fact impossible that sewage could arrive at the water, but it is wrong data altogether.

6110. Do you consider that there is not so much reliance to be placed on the analysis of Dr. Frankland as upon that of Dr. Letheby?—I do not think that there is any material difference at all in the analysis, but simply in the comment upon it. Having analyzed it, Dr. Frankland says that the nitrates have a sewage origin; but I say that it is not necessary that it should be so. Besides, Dr. Frankland at the commencement of this year had one theory, but he has now changed it for another.

6111. (*Chairman.*) One of the theories is that the maximum solid impurity is 41·74, as against the river Lea 26·60; is that a theory, or is it correct?—I believe that is quite correct. Impurity there must not be taken in the popular sense of the word; it means the mineral and other constituent parts of water. If you take it in the popular sense as meaning dirt, it does not mean that, nor does Dr. Frankland intend to convey that opinion.

6112. Is the only thing that you find fault with the estimate of the previous sewage contamination?—That is the only objection I have. I have no objection to the nitrates that Dr. Frankland finds in the water. I only object, as all chemists object, to the statement that those nitrates are due in the case of chalk water to previous sewage contamination. For instance, upon that data, if you refer to Dr. Frankland's report for August, you find he reports that the river Lea contained no sewage contamination at all, which is a manifest absurdity. Again in the case of the well at Grays which supplies the South Essex Company, that was supposed to contain 8¼ per cent. of equivalent to London sewage. That it contained nitrates that London sewage would contain, there is no doubt, but that it was sewage itself is utterly impossible.

6113. (*Sir J. Thwaites.*) As far as your present supply is concerned, drawing it from deep wells, it is quite clear that there can be no sewage contamination?—The impression abroad is that it is absolutely a mixture of sewage with our water supply.

6114. I understand your system is now so perfect and so entirely distinct from the original source of supply, namely, from the valley of the Ravensbourne, that you draw the whole of your present supply from deep wells?—The whole.

6115. Is there any place between the lift and the source of supply into which sewage can flow?—None.

6116. (*Chairman.*) Will you be kind enough to describe the mode that you adopt in order to get the water?—The greater part of our wells have the chalk very near the surface. We pass closed cylinders of iron from 70 feet to 100 feet down, so that we effectually exclude all the surface water, and we then proceed to bore or drive, as the case may be, until we obtain the quantity of water which we require.

6117. Is there no possibility of any soakage going into those chalk wells from the cultivation of the land?—It is utterly impossible. Whatever soakage there is must be that which would come in by infiltration. The whole of this chalk water has its origin in the rain falling upon a district lying very wide, and it filters through the chalk and passes down 200 or 300 feet, and rises finally out of our wells.

6118. But if the water be due to the rainfall passing through cultivated land, would it not possibly take the sewage through to the wells?—There is no doubt that the nitrates of Dr. Frankland may have their origin from that source, but at the same time they are changed from their original form of ammonia into nitrates, and that very change supposes the conversion into a harmless compound.

6119. And has that rain passing over and flowing upon the ground, and then through the chalk into the well, by the time it gets down to the bottom of the well been relieved of its impurity?—Yes; in fact it

W. R. Morris, Esq.

26 Feb. 1868.

is the great laboratory of nature. The whole body of chalk acts with precisely the same effect as is recommended by filtration through animal charcoal. Precisely the same result is arrived at, on a very large scale, as is proposed to be done by the experiments of the chemists of the present day.

6120. Have you any knowledge of the wells at the Woolwich Arsenal?—None, but their water is not so good there. I have not analysed it, but I know that we supply the arsenal with water from our wells.

6121. Then you do know the wells that supply the arsenal?—We supply the arsenal with water, I suppose, in preference to their own water which they have there.

6122. You admit that your water is some degrees harder than the river Lea, and the East London Company's water?—I should think it is.

6123. Twenty-seven, 19, and 18, are the relative figures. Do you agree with that?—I should say that that is quite correct.

6124. And the Grand Junction 19?—Yes. I may say that after five minutes boiling the waters all become equal.

6125. You mean equal to the other before it is boiled?—No; if you boil the river Lea water and the Kent water, which is chalk water, you will find them to be both of the same degree of hardness.

6126. Have you any experience of Dr. Clark's process?—I have not. We took possession of the Plumstead works, where the process had been going on for some years, but we did not carry it on. We found the whole thing so imperfect and so utterly not to be depended upon, that we were obliged to abandon it. The only instance where Dr. Clark's process was carried out on a large scale was at the Plumstead works, and I may mention that the water softened by that process seemed to have a great effect upon the lead cisterns in that district. We found in many instances that the cisterns were perfectly destroyed. That shows that you may carry the system of softening water to too great a length—that a certain amount of lime is necessary to preserve water from contamination from lead.

6127. The water supplied by your company has been used, has it not, by a very large district?—Yes.

6128. Have you any means of telling us how many gallons per head per day you supply?—About 25 gallons.

6129. Is that the gross quantity?—Yes, we have not many manufactories in our district.

6130. How would you make that quantity up; how much for domestic purposes?—I do not distinguish between the two; dividing the total quantity pumped by the number of houses, comes to about 25 gallons per head per day, and as we have very few manufactories in our district that fairly represents the quantity of water which is used per head per day.

6131. What do you allow for waste?—I cannot distinguish between use and waste. There is no saying where the one ends and where the other begins.

6132. (*Sir B. Phillips.*) What is the population of your district?—I am not prepared to say that either; we supply 35,000 houses.

6133. What is the gross quantity of water per diem that you pump?—I do not remember the exact quantity, but I have prepared a diagram showing the increase from 1840 to 1867, which I will beg leave to hand in to the Commission. (*The same was delivered in. Vide Appendix S.*)

6134. (*Chairman.*) According to this diagram in the year 1840 you supplied 120,000,000 gallons in the year?—Yes.

6135. And you now supply 2,040,000,000 gallons in a year?—Yes.

6136. And the gradual increase is shown in this diagram?—Yes.

6137. Is the part coloured dark blue in the diagram that which you derive from the river Ravensbourne?—Yes, and the light blue is derived from springs.

6138. In the years between 1855 and 1860 you had completely exhausted the Ravensbourne, had you?—Yes, at that point where the dark blue ends, and it gives the date when the river Ravensbourne was thoroughly exhausted. In fact the dark blue will show the flow of the Ravensbourne; we took it all.

6139. (*Sir J. Thwaites.*) Now are you supplying both the dark blue and the light?—Yes, we substitute well water for the Ravensbourne water.

6140. (*Chairman.*) Now you get your supply for all the district from the deep wells in the chalk, and you take nothing from the river. Is that because there was nothing left?—No, we have abandoned the Ravensbourne altogether.

6141. Can you form any opinion as to the amount of water that there is in the district from which you gather your supply?—At present we are supplying about 7,000,000 gallons a day; in round numbers we have machinery for raising 10,000,000 gallons, and our present wells will certainly supply 14,000,000 gallons, that is double our present day's consumption; and I have not the slightest doubt that if we went further down we could obtain any amount that we chose, that is to say, selecting certain portions of our district we could find a spot where we could get more water still.

6142. How deep do you go?—We vary from 200 to 250 feet. In one case we are about 500 feet down, but that is a small well.

6143. (*Col. Harness.*) Do you mean from the surface or below any fixed level?—From the surface.

6144. How much are the wells sunk generally below Ordnance datum?—The surface of the principal part of our wells is about 12 feet above Ordnance datum.

6145. (*Sir J. Thwaites.*) Have you depressed the water line by your pumping?—Not permanently.

6146. Have you watched that?—Yes; if we stop any of our wells the water immediately rises to its former height, which is about two feet above high-water mark.

6147. Is there any infiltration from the Thames?—No, some of our wells are miles from the Thames.

6148. (*Chairman.*) Have you at all taken into consideration the Thames basin as a source of supply, or has not that come within your knowledge?—No, I have never taken that question up.

6149. (*Mr. Harrison.*) Is the report which you have handed in in the nature of a monthly report made to your company by Dr. Letheby?—No; Dr. Letheby analyses twice every month our water, and makes a report; this is a special report.

6150. (*Chairman.*) Has your attention been turned to the question of constant service?—It has very much.

6151. What conclusion have you arrived at as to the benefit of that system to the population generally?—I am very favourable to a constant supply.

6152. First of all, will you state what is your supply?—Our supply is intermittent, except where it is by meter.

6153. You have reservoirs in the houses, I presume?—Yes. If we could get rid of the waste we would adopt the constant supply directly.

6154. Then the provisions of the Act of 1852 have never been put into operation in your district?—We have never had the slightest application for it.

6155. But you think that a constant supply would be a very good thing?—I do, if we could once prevent waste, or if we had power given to us to prevent it, or any mode were devised by which we could get rid of the enormous waste which is attendant upon a constant supply as carried out under the present system, we have no objection.

6156. When you say if you could get power given you to do so, have you ever considered what powers would be satisfactory for preventing waste?—I think that the power which would be required must be vested in what we may call a water police; there should be a constant inspection, which I know that the public would not bear, but unless we had power to exert that it is perfectly out of the question. I have made some experiments, and I know that people have wasted as much as 2,000 gallons a day per house for

a twelvemonth together ; and in the case of meters, we supply by meters because then we do not care how much they waste, as they have to pay for it, but they complain in several instances, especially by persons unacquainted with the system of the amount of their bills. The question is to find out how those bills arrive at such an amount. We find that they themselves with all their care cannot prevent waste, and can hardly account for it. A pipe gets broken or a watercloset is left running, and away goes a million gallons of water before you know where you are.

6157. In such a case the house would be flooded ?—It is so ; a pipe broke across a drain the other day in a large house at Blackheath, and the loss of water was enormous before the defect could be discovered.

6158. (*Sir J. Thwaites.*) Having regard to a properly arranged system of supply, pipes of sufficient strength to resist the pressure, and an efficient supervision, you are of opinion in the first place that a constant supply would produce a great saving of water, and in the second place promote the health of the inhabitants ?—I will confine myself to the saving of water. I have no doubt there would be a great saving of water, but the restrictions must be very stringent, otherwise it would completely absorb the whole of our power of supplying ; you might pour water upon the sea beach with as little effect.

6159. (*Chairman.*) You think it necessary, if I understand you aright, to have some very stringent police regulations ?—I do not say police, but something of that nature, persons armed with authority who could go into the houses and prevent waste.

6160. That is to say, in order to see that the taps and cocks and pipes are in good order ?—Yes, to see that they are kept closed.

6161. (*Col. Harness.*) Have you ascertained what the average consumption is per head where the supply is given by meter ?—It does not seem to vary. I do not perceive much difference between the supply to a private house with a meter and without it ; that is to say where things are properly regulated, the charge by meter comes to about the same sum as we should charge to the house without a meter.

6162. (*Chairman.*) Do you say that you pump 7,000,000 gallons a day ?—That was our last year's pumping, our average does not come so high as that for the whole of the years.

6163. And you could get by extra machinery 10,000,000 gallons ?—14,000,000 gallons is certainly the yield of the present wells.

6164. You said that you could get a much larger supply ; is it possible to form an idea as to what supply you could get, whether it would be double or treble that ?—I should not like to speak as to that. It ought to be, that is all I can say.

6165. (*Mr. Harrison.*) Is yours a healthy district generally ?—Yes, very.

6166. What is about your death rate ?—I do not know the death rate, but in Lewisham and Blackheath the death rate is the lowest in the whole district, and as low as in any of the metropolitan districts.

6167. Have you ever had any complaints of the effect on health of the supply of water in your district ?—No, nor any complaints at all of the water.

6168. (*Sir J. Thwaites.*) They have not reached you, I presume ?—They must reach me if there are any complaints.

6169. (*Mr. Harrison.*) Is this question of sewage contamination a new mode of estimating the quality of water ?—Yes.

6170. How long has it been introduced ?—I cannot say exactly, but it can be ascertained by reference to the Registrar General's returns ; but within the last two or three months Dr. Frankland has again changed his estimate and formed a new one. It is found, in fact, that the nitrates exist largely in rain water, that is to say, those nitrates which are supposed to be due to sewage. You have a very large per-centage of ammonia in every shower of rain that falls during a thunderstorm, and under ordinary circumstances no rainfall takes place without some amount of ammonia, which produces those nitrates.

6171. (*Chairman.*) Then your evidence goes to show that the nitrates which are found in your water are what are found in all rain water and therefore are not attributable to sewage contamination ?—Not precisely that. I do not mean to say that you will find in rain water the amount of nitrates which you will find in chalk water ; still there are nitrates in rain water, and according to Dr. Frankland's theory it ought to be sewage, and sewage is out of the question in the case of rain water ; but I have no doubt that the chalk, which is nothing but a mass of organic remains, contains in itself large quantities of nitrates due from those remains, but they are perfectly harmless. I never heard Dr. Frankland or anybody else say that there was the least detriment whatever from the use of those nitrates, and the water itself is perfectly pure from any organic matter.

6172. (*Col. Harness.*) Do you find that your wells at Deptford, when you are not pumping from them, vary in level with the state of the tide in the Thames ?—No, I do not observe any variation whatever. We have three wells at Deptford, and to give you an idea of their yield, if we stop any one well and keep the other two wells pumping, that well which we stop rises to its original level, although the wells are within 300 yards of each other, and their level is about two feet above high-water mark, and when the tide falls we do not perceive any difference.

6173. What distance are they from the Thames ?—I suppose about a mile.

6174. (*Chairman.*) I see under the head of "ammonia" that your water is ·003 and the Lea water ·006 ; therefore there is more ammonia in the Lea water than in yours ?—It varies very much. I do not place much reliance upon that. The amount is so infinitesimal when you come to calculate it out, one in 50,000,000 parts, that it is hardly appreciable.

6175. (*Mr. Prestwich.*) Will you put in your evidence that paragraph in the report of the year 1851 in which Professors Graham, Hofmann, and Miller express their opinion of the quality of chalk water ?—It is the last concluding paragraph in the report, and it is in these terms : "The water recommended "appears to approach most closely to the standard "of all that is excellent in a town supply, and "is worthy of the greatest efforts and grandest "works to procure and convey it. But the sources "are near at hand and the water is attainable without "difficulty or great expense. With such a noble "application of the chalk spring water in view as the "supply of the metropolis, it would be a desecration "to permit that water to be wasted on other uses, "and most impolitic to allow the possession of it to "pass into private hands. It is our deliberate opinion, "which we would enforce in the strongest terms, that "the much desired and most necessary improvement "in quality of the London water is associated with "these sources of supply, and will depend upon their "proper application to the uses of the public."

6176. You have increased the number of wells according to the increased demand for water, have you not ?—Yes.

6177. And as you have still a district in which the demand increases do you see a limit, by increasing the number of wells, to the power of sufficient supply for that district ?—We conjecture so ; of course it must be conjecture. Hitherto we have not made a mistake, but I do not mean to say that we might not select a spot which would be worthless, but I have no doubt that we could get an incalculable amount.

6178. Have you been successful in obtaining water in all the wells which you have sunk ?—Yes, in all the wells.

6179. At the different levels ?—Yes. We have one well where the water stands 70 feet above Trinity high-water mark.

6180. In sinking those wells you had I presume in most cases to go to a certain depth before you reached the source of supply, that is to say, you did not meet

W. R. Morris, Esq.

26 Feb. 1868.

with water at the same level or indifferently in the chalk as you proceeded?—No, we generally find a good deal of water in the chalk immediately we pierce it. It depends of course upon the situation. At Deptford we find most water at about 100 feet down.

6181. When you come upon a spring, do you usually meet with a spring of considerable force, or do you extend your well by galleries, so as to increase the source of supply?—We work both ways. We generally select a spot as near as we can upon a fault, and having found the spot we sink down, and we sometimes have obtained water immediately by boring without any further trouble whatever; an 18-inch bore-hole takes us down to it, but in some cases we have had to drive adits into the chalk, and to collect the water as we went on. We generally find that a great quantity of water comes from the bottom of the springs upwards.

6182. Is there anything to indicate that any infiltration takes place in the vicinity of the well itself?—No; nearly the whole of the water seems to rise up from the floor of the adit in which we are working, and it is drawn from a distant source where the chalk comes to the surface.

6183. Have you had the waters from the different wells analysed?—Yes, the whole of them.

6184. Do you find much difference in the composition of the water?—There is a considerable amount of difference between the wells in that respect.

6185. In the proportion of nitrates do you find them to vary?—They do vary, and they vary sometimes according to the seasons. I cannot account for it, but they do vary slightly according to the seasons; and we find that pumping a well after a few years slightly hardens it, that is to say, we get a slight increase of carbonate of lime.

6186. Is not that rather contrary to the notion of the usual action of wells, where the more you draw upon them the less mineral matter they contain?—Yes. I mention that because it is a fact which I was not prepared for when I first commenced searching for water, but so it is, that we get more carbonate of lime as years proceed; there is a slight difference, instead of softening the water gets slightly harder.

6187. How is it as to the other substances?—They remain about permanent.

6188. Has Mr. Wanklyn applied his test to the water from those wells?—I do not think he has. I have not seen any report of it if he has.

6189. (*Chairman.*) Are we to understand you distinctly to say that the reason you left the river Ravensbourne was that you had exhausted its power, there was no water left in it?—We pumped the whole that came down, and having a larger demand we sought for water in the chalk, and having discovered it, we found that it was much better water than that which we had obtained from the Ravensbourne, it pleased the public much better. It required no filtration, and the result was that we adopted the chalk water and abandoned the other.

6190. (*Mr. Harrison.*) I asked Mr. Quick a question as to the cost of pumping. Can you give us any information upon that?—No, I cannot. The cost of pumping varies so much in each establishment that we have that I can give you no data. If I were asked to give a formula to determine the cost of raising water to given heights, it could be done, but it would be a great deal of trouble, in our case particularly.

The witness withdrew.

The witness subsequently sent in a copy of the following letter:—

(Copy.)

University College,
25th February 1868.

Dear Sir,

I have the honour to report the following results of my analysis of the water supplied to me at Bromley on the 18th inst., and reported to have been drawn from a main of the Kent Waterworks.

The water contained, dissolved in 100,000 parts—

Solid residue	32·7
Nitrogen, as Nitrates and Nitrites	·403
Organic Carbon	·064
„ Nitrogen	·044
Ammonia, a trace not above	·002

Total hardness of the water is 21·7 degrees, and the permanent hardness 4·8 degrees.

I remain, yours faithfully,
(Signed) A. W. Williamson.

R. Latter, Esq.

Adjourned to to-morrow at 12 o'clock.

Thursday, 27th February 1868.

Present:

His Grace THE DUKE OF RICHMOND in the Chair.

Sir John Thwaites.
Alderman Sir Benjamin Phillips.
Colonel Harness, C.B.
Thomas Elliot Harrison, Esq.
Joseph Prestwich, Esq.

Dr. Edward Frankland, F.R.S., examined.

Dr. E. Frankland, F.R.S.

27 Feb. 1868.

6191. (*Chairman.*) What position do you hold?—I am a Fellow of the Royal Society, Corresponding Member of the Imperial Institute of France, and Professor of Chemistry in the Royal Institution and in the Royal School of Mines.

6192. You have had great experience, have you not, with regard to the chemistry of potable waters?—During the last three years I have been engaged in examining monthly the waters supplied to London for the Registrar General's Report; and consequently I have been brought a good deal into contact with those waters as a chemist, and during that time, and I may say for the last 20 years, I have been also more or less engaged in the same kind of work.

6193. You have been engaged recently, have you not, in connexion with Dr. Odling in analysing samples of waters collected in North Wales and Cumberland and Westmoreland?—I have.

6194. Were those the samples of water which were handed to you by Mr. Pole?—They were.

6195. You are probably aware that he went down at the instance of this Commission to the lake districts and to Wales for the purpose of collecting samples in order to have them analysed by yourself and by Dr. Odling?—Yes, and I received at the same time Mr. Pole's reports upon the collection of those samples in the two districts.

6196. (*Sir J. Thwaites.*) Have you seen the evidence which Mr. Wanklyn gave before this Commission?—I have.

6197. Have you observed that in that evidence he lays down some fresh principles or analytical arrangements, more especially with regard to water?—Yes.

6198. He does not agree with you in your mode of separating the elements or describing them, and he states in that evidence that Dr. Frankland is now pretty

much of the same opinion with himself as to the proper mode of analysing the water. Before you go into your general evidence, will you have the goodness to state whether you are agreed in your mode of examining water, or whether you are still at issue upon that point?—We are still I think entirely at issue upon that point, as we always were; Mr. Wanklyn and Mr. Chapman proposed early last year a new mode of examining waters with regard to the organic nitrogen which they contain, founded upon the chemical reaction between permanganate of potash and albumen. The process did not on *à priori* grounds inspire much confidence in the minds of chemists as to its service when applied to waters, because we not only do not know that water contains any albumen whatever, but the nitrogenous organic principles contained in water are so utterly unknown to chemists, that any process founded on a reaction upon one particular species of nitrogenous organic matter could not with confidence be applied to potable waters containing unknown principles of that kind.

6199. Then we are to understand that you still adhere to your mode of examining waters, and that you are not, as alleged by Mr. Wanklyn, of opinion that his process is the proper one to ascertain the constituent elements of water?— Certainly not. I never expressed any such opinion. When he stated that in his evidence, he must have mistaken the purport of some conversation that we had upon the subject. But perhaps I may be allowed to state that at the time his process was proposed, my colleague, Dr. Odling, and myself thought that we should not be justified in ignoring it, therefore we have submitted every sample of water collected from the two districts for this Commission to Mr. Wanklyn's process, and the results of those analyses are contained, with our own results, in our report which has been already presented to the Commission. That result will be found in each table under the head of "ammonia evolved on boiling with permanganate of potash." At page 4 of the report under the head of "other determinations and estimations," you will find "ammonia ob- "tained by distilling 100,000 parts of each water with "permanganate of potash." That is the determination of Mr. Wanklyn and Mr. Chapman, and we comment upon its results, in relation to the process which we adopt in these analyses, in another part of the report, or rather I comment upon it; but I may mention that my colleague is perfectly agreed in this comment. At page 12 there is this paragraph:—"In addition to the organic "nitrogen as thus determined by direct analysis, we "have also estimated the amount of ammonia which "is evolved from the waters by prolonged ebullition "with a strongly alkaline solution of permanganate of "potash, the ammonia previously existing in the "water being first expelled by ebullition with car- "bonate of soda. This method has been recently "proposed by Messrs. Wanklyn and Chapman as a "means of determining the organic nitrogen in "waters. In our hands this process has yielded "somewhat irregular results. As a rule, which is, "however, by no means without exceptions, the "organic nitrogen so inferred is considerably less "than that obtained by direct analysis, and this is "markedly the case with those waters which contain "a comparatively large amount of organic nitrogen; "thus, the flood water of Troutbeck (Greta) gave us "by analysis ·068 part of organic nitrogen, whilst the "same water when boiled with alkaline perman- "ganate gave only ·016 part" (or only about one-fourth); "whilst, therefore, this process is valuable "as a ready qualitative method of ascertaining the "presence of organic nitrogen in waters, we do not "think that in its present form it can be relied upon "for the determination of the actual amount of this "element." I may mention also that since this report was written I have had further opportunity of testing the permanganate of potash process with several kinds of organic matter of known composition, in which a certain amount of nitrogen is known to exist, and in every case it has signally failed to evolve even a considerable proportion of this nitrogen in the shape of ammonia.

6200. (*Chairman.*) We have now before us your report upon the waters after having analysed them, in which you seem to have gone very fully into the subject. Is there anything which you would wish to add to the report?—Your Grace will see that there is a special part of this report which has been written by myself, and in which I endeavoured to embody that which at the time occurred to me to say respecting the analytical results, and their bearing upon the question before the Commission. At page 6 you will find "additional observations by Dr. Frankland."

6201. Could you give us briefly what is the result of your examination of the waters?—The result of the examination of the waters from both districts is, that with the exclusion of a few samples which are mentioned particularly in our report, the waters from both districts are very well calculated for the supply of a large community like that of the metropolis.

6202. Would there be any effect produced upon the waters by storing them in large quantities in reservoirs?—So far as my experience goes in the storage of waters the quality appears to be greatly improved by that storage, and therefore I should expect that in those districts where there are no large lakes to be experimented on at present, the quality of the water as now revealed by analysis would be improved if stored in large reservoirs.

6203. Would peat have any effect on those waters?—Peaty matter is probably contained to a greater or less extent in all those waters, and probably in every water that ordinarily comes before us. Almost all potable waters appear to contain a minute quantity, at all events, but the proportion of peaty matter in soft waters is usually considerably greater than in harder waters. The proportion of peaty matter in some of the water, both in the Cumberland and in the Welsh districts, in some few of the samples which are particularly mentioned in our report, is large—in fact too large to admit of their being used for a water supply in that condition. For instance, in the case of the Trout Beck (Greta), in flood, that sample contained too much peaty matter to be admissible into a town; and the Mosedale Beck, in flood, is another example where too much peat is contained to render the water a desirable one. But by storage in large reservoirs much of that peaty matter would, in all probability, be precipatated before the water would be drawn off from the reservoir.

6204. But would not all the supplies from both those districts be liable at some period of the year to great quantities of flood water?—I presume they would, if it should be found necessary to collect all the flood water and make use of it; but there are contrivances which I have seen in use at the Manchester Waterworks, for allowing the flood water, by shooting over a slot in a conduit, to escape from the reservoirs used for supply, or, at all events, those used for immediate supply.

6205. What is the case; is it not that floods in those districts take place in the course of half a dozen hours?—Yes.

6206. And the water remains in flood for 24 hours sometimes, or more?—Yes.

6207. Then all that water would contain, would it not, a great quantity of peaty matter?—In some cases it would, but the conduits of which I have spoken are self-acting; they do not require anyone to be present to shut off the flood water; the flood water shuts itself off. The moment the volume of the stream exceeds a certain maximum the flood water jumps over the slot through which it had previously been running.

6208. (*Sir J. Thwaites.*) Is there any process by which the discolouring matter can be removed from the water other than by precipitation?—There is a very excellent process for its removal which could also be carried out upon a large scale, and at no great expense, that is, filtration through animal charcoal, which effectually removes it.

Dr. E. Frankland, F.R.S.

27 Feb. 1868.

6209. Is there anything in the idea of the stain in the water caused either by peat or any other coloring substance, so that it is difficult to remove it afterwards, either by filtration or any other process?—The ordinary process of sand filtration will not remove much of the colouring matter, but filtration through animal charcoal removes the whole of it. The colouring matter, I may mention, constitutes apparently only a small part of the organic portion of the peaty substance that gets into the water.

6210. (*Chairman.*) Water may be very much coloured after flood and still be very wholesome to drink, may it not?—Yes, certainly; and if we are to take as examples the kind of water which would probably come from large reservoirs in the Welsh district and in the Cumberland district, that water would contain a less amount of peaty matter than is frequently contained in the Thames and river Lea water at the present time.

6211. Are you of opinion that the samples taken by Mr. Pole are sufficient to give us a very perfect idea of the quality of the water in both those districts?—I think they are. The samples were taken under considerably different circumstances in the various cases, sometimes in flood, and from the same streams again in moderate weather and good weather, so that on the whole I think these analyses give a very good idea indeed of the quality of the water which would be obtained from both districts; but inasmuch as, in the Welsh district, we have no lake in Mr. Bateman's gathering grounds, the evidence there is by no means so conclusive as it is in the case of the Cumberland and Westmoreland district.

6212. Would you explain why that is?—Because we have no means of judging of the effect of storage. However, the water of the Bala lake, which is just outside Mr. Bateman's district, may probably be considered as affording an example of the kind of water which would be obtained in Mr. Bateman's large reservoirs.

6213. Did you detect any effect upon the water from mineral workings?—With regard to turbidity we did in several cases. Some of the samples collected by Mr. Pole were turbid at the time of collection, and they retained their turbidity for some weeks afterwards. All those samples which flowed from mineral workings, or were contaminated by water from mineral workings, were specially examined for noxious mineral substances, and we found in either two or three cases the merest trace of lead; but in all other cases no metallic noxious substance of any kind was present.

6214. Was that with reference to water from the lake district, or from the Welsh district, do you recollect?—I think it was in samples from the lake district exclusively that that trace of lead was found. But I may mention that the trace was so utterly insignificant that it was only just capable of being revealed by the most delicate chemical processes, and the notion that it might be hurtful when mixed with the rest of the water, or even hurtful if that water alone were drunk, is quite out of the question.

6215. You have also had great experience, have you not, with regard to the waters of the metropolis?—For the past three years I have had my attention very specially directed to those waters.

6216. Could you state first of all whether the waters which are now supplied to the metropolis are hard or soft waters?—They are what I should call hard waters, having from 14·4 up to 28·8 degrees of hardness. But I must mention that there are two kinds of degrees of hardness. These I have just quoted are the degrees of hardness mentioned in the reports to the Registrar General, and these degrees are only seven-tenths of the value of the degrees that were proposed by Dr. Clark, of Aberdeen.

6217. What would be the degrees of hardness of the water from the Welsh district, as proposed to be supplied by Mr. Bateman?—The Welsh waters, exclusive of Bala lake, would be from 3 degrees the maximum to ·7° as the minimum, and these degrees, as I before stated, are each of the value of seven-tenths of Dr. Clark's degrees.

6218. (*Sir J. Thwaites.*) Does that process of examination run through all your reports?—Through the whole of them; it is a form of expression in this report, and in all the reports to the Registrar General.

6219. That applies also to the lakes as well as the London waters?—Yes, to the lakes, to the London waters, and to the Welsh waters, and I may say also to the French waters.

6220. (*Mr. Prestwich.*) Would you be able to give us also the degrees as used by the other witnesses?—Yes, certainly, there is nothing so easy. It is only necessary to multiply by ·7.

6221. (*Sir J. Thwaites.*) It is very important that we should upon your testimony have an accurate statement of the degrees of hardness of the London waters, and of the degrees of hardness of the Welsh and the Lake waters, and that we should keep to the same language as other chemists, namely, the degrees applied to the gallon, as by Dr. Clark, and not to the litre?—The degree of hardness upon Dr. Clark's scale of the Welsh water, exclusive of Bala lake, is 2·1 as the maximum, and the minimum is ·5. The hardness of the Cumberland water (exclusive of the Lower Lowther and Dacre Beck) varies from 2 degrees to ·5. The hardness of the London water varies from 10·1 degrees to 20·2.

6222. (*Chairman.*) What does your experience tell you is the effect of the quality of the present supply in London upon the health of the population generally?—I cannot of course trace any direct connexion between the present supply and the health of the metropolis; but I consider that water contaminated with sewage contains that which is noxious to human health. There is no process practicable upon a large scale by which that noxious material can be removed from water once so contaminated, and therefore I am of opinion that water which has once been contaminated by sewage or manure matter is thenceforth unsuitable for domestic use.

6223. That is a proposition; but is there that sewage contamination in the London water?—There is undoubtedly that in the London water, which is self-evident from the circumstance that sewage flows into the Thames and the Lea. It is not so self-evident in the case of the chalk water supplied by the Kent Water Company, but chemical analysis reveals that it is there also present.

6224. Are we to understand that you are of opinion that this noxious matter exists in the water from analysis, or from knowing that sewage runs into the river from whence the companies draw their supply?—From both circumstances.

6225. Take the analysis first. What leads you to believe that there is that amount of sewage matter in the water which would be detrimental to health?—I find on analysis, as is shown in the table at page 17 of our report, that there is present in the waters delivered into London the following quantities of material, which may be regarded as the skeleton of the sewage which has been previously poured into the water; namely, of nitrogen, in the form of nitrates and nitrites, a mean quantity of ·192 part in 100,000 parts of water, that is, in the Thames water; in the river Lea water, as delivered by the New River Company, ·221 part in 100,000 parts; in the water delivered by the East London Company, which is also river Lea water, ·132 part; and in the chalk water delivered by the Kent Company, ·365 part in 100,000 parts. This skeleton, as I have called it, of previous sewage corresponds to the following quantities of average filtered London sewage, namely, in the Thames water to 1,751 parts of sewage in 100,000 parts of water; in the river Lea water, delivered by the New River Company, to 2,013 parts of such sewage; in the river Lea water, delivered by the East London Company, to 1,077 parts of such sewage; and in the chalk water delivered by the Kent Company, to 3,393 parts of such sewage. I must mention, however, that this chemical record is defective, especially in the summer months. It is defec-

tive in one direction, namely, that it gives the minimum amount of sewage only, with which the water has been contaminated; because in rivers we have vegetation in a state of activity during the spring and summer months, and also to some extent in autumn, and those aquatic vegetables remove this skeleton of the sewage to a greater or less extent from the water.

6226. You state that you have come to the conclusion that sewage has been the cause of the contamination of this water, because you find a skeleton there in the form of nitrates and nitrites?—Yes, and also of ammonia, which I think I omitted to mention, but that is a very insignificant part of the skeleton.

6227. Is it possible that those nitrates and nitrites could be present in the water without its having been contaminated by sewage? Could they be produced by some other cause than that of sewage?—They could be caused by manure thrown into the water, and by manure applied to the land.

6228. But are they attributable to nothing else?—To nothing else, I believe.

6229. With regard to the chalk water delivered by the Kent Company, you state that the mean is ·365 of nitrates and nitrites, which represent in the other column an estimated previous sewage contamination amounting to 3,393; that water we understand is taken from wells which are some 200 feet below the surface?—It is, I believe.

6230. Would the sewage get down that depth?—The skeleton of the sewage would get down that depth, and even might get down much lower than that. Nearly the whole of that water is the drainage from cultivated land, and that which is not the drainage from cultivated land is the drainage from pasture land; and according to the analyses of Professor Way of drainage waters from land, those waters contain the following quantities of previous sewage contamination in 100,000 parts. The drainage water from manured arable land contains between 54,490 parts of previous sewage contamination as the maximum, and 7,040 parts as the minimum, the average being 20,370 parts of previous sewage contamination in 100,000 parts. From unmanured pasture land the maximum is 2,100 parts of previous sewage contamination in 100,000, and the minimum 180 parts, giving an average of 830 parts.

6231. How do you account for those nitrates and nitrites not being present in the waters which were collected in those two districts of Wales and Cumberland?—Because there is no such pasture land as that which was experimented upon in the case of Professor Way's experiments. This is water which has percolated through the pasture land and made its escape from drains; whereas the water that was collected for analysis for this Commission was principally, I believe, surface drainage, water that flowed rapidly over the surface and made its way very rapidly into the stream. None of the land, or very little of the land, is there systematically drained; but there are cases, especially in the Welsh district, where this previous sewage contamination is actually indicated by analysis, as will be seen by referring to the report, it occurs where cultivated land exists on the sides of the streams, and so far as I can gather from Mr. Pole's report, such land does occasionally exist there.

6232. It would be pasture nearly the whole of it, would it not?—It would be sparsely pastured by sheep, I presume, and cattle. The minimum in this unmanured pasture land, according to Professor Way, is 180 parts, and we have a larger amount than that in some of the Welsh samples.

6233. (*Sir J. Thwaites.*) Before leaving that part of the examination with regard to the Kent water, we had some evidence yesterday to the effect that you must have been mistaken in finding traces of sewage in those chalk wells, the water being taken at a depth of 250 feet in the chalk, and the upper part of the wells themselves being lined; therefore the water must have filtered through the chalk, and there could be no trace of the skeleton of sewage. Is it your opinion that the skeleton of sewage as you describe it will find its way down to a depth of 250 feet, and that after filtration through gravel, and ultimately through the chalk, its presence will still be detected?—There cannot be a doubt about it, that this skeleton of which I speak, but which is a very different thing from the sewage itself, is present. I have never stated that the water which has filtered through the chalk in this way contains unaltered sewage; it is this inorganic skeleton of sewage that I find in water so filtered.

6234. Is it prejudicial to health?—It is not in a moderate quantity, such a quantity, for instance, as is contained in this chalk water of the Kent Company.

6235. (*Chairman.*) With regard to the Kent water, the mean of the nitrates and nitrites according to the figures which you have just given us is ·365, and that amount in water in your opinion would not render it injurious to health?—That amount of nitrates I should say would have no deleterious effect upon health.

6236. It is scarcely necessary to say that in the case of the water delivered by the East London Company, which has ·132, the water of the River Lea Company, which has ·221, and the Thames water delivered by the Chelsea and Grand Junction and other companies, which has ·192, none of those four waters as at present supplied to London could have an injurious effect upon the health of the metropolis, in consequence of the presence of those nitrates which you say are the skeletons of previous sewage contamination?—Certainly not. Those nitrates would not in any case, I believe, be in the least prejudicial to health; but they reveal the fact that those waters have been previously contaminated with sewage, and, as I have already stated, there is no method which, with certainty, can be applied to water by which the noxious qualities of sewage can be effectually removed from it.

6237. But in all those four waters, as I understand you to say, after having had them analysed, you find the presence of those nitrates and nitrites, which shows that the waters had been in previous contamination with sewage?—Yes.

6238. But although they are in that state, you state, do you not, that there is nothing in them that could be injurious to health, and therefore the water is a wholesome water to drink?—I did not intend my statement to go so far as that. I meant only with reference to those nitrates in themselves, that the skeleton of the former sewage which is represented by nitrates and nitrites is not injurious to health; but we have no guarantee that other portions of that sewage may not have escaped the process of filtration through the chalk, and filtration through the land or over the land, and may be present in that water. Those substances are in too minute a quantity to be capable of detection by chemical analysis.

6239. Then your answer would apply as far as the nitrates would enable you to judge?—As far as the nitrates themselves are concerned that quantity of sewage matter which they represent is in an innocuous form in the water.

6240. The presence of what other elements would lead you to a conclusion upon the quality of water as regards health?—In the first place when water is once contaminated with sewage, there is no process to which it is afterwards subjected which will effectually remove all that sewage contamination from the water. Filtration will not do it in certain cases, at all events. I have proved that the excrements of cholera patients cannot be filtered out of water; that after a degree of filtration which I believe is never attained by the water companies, and rarely attained perhaps by the passage over soils in irrigation, this water still remains opalescent, from the rice-water evacuation with which it has been mixed. The degree of danger which still remains in waters from different sources varies obviously according to the amount of filtration that the water undergoes. I would much rather drink the chalk water of the Kent Company, even if it had been contaminated to four times the extent of the Thames water, than I would drink the Thames water, because if I could have the assurance that none of that sewage

Dr. E. Frankland, F.R.S.

27 Feb. 1868.

or manure water had found its way into the wells through fissures in the chalk, the chalk water having passed through say 100 feet of chalk, would be very much better filtered than any water which finds its way to the Thames.

6241. (*Sir J. Thwaites.*) When you speak of the difficulty of removing the effects of sewage contamination, does that difficulty apply to that which is held in mechanical suspension, or to that which is held in solution?—To that which is held in mechanical suspension. I believe that the noxious part in sewage is that which is held in mechanical suspension, not that held in solution.

6242. Will no system of filtration remove it?—I would not say that it is impossible to remove it, but no system of filtration will secure its removal. There are only two processes by which it can be effectually removed; the one is by boiling for a long time, and the other is by distillation; and therefore it is that I say that, inasmuch as those two processes are impracticable on a large scale, in my opinion water that has once been contaminated by sewage ought not afterwards to be used for domestic purposes.

6243. (*Chairman.*) I see in your report to the Registrar General, dated the 31st of January in this year, "The waters delivered in London during the "latter part of January by the Chelsea, and especially "by the Southwark and Lambeth companies, were "in such a muddy condition as to render them totally "unfit for domestic use. The Thames has overflowed "its banks above the point at which the water supply "is withdrawn, and by washing the surfaces of cultivated fields, and mingling with the contents of "stagnant ditches and ponds, has become contaminated to an intolerable degree. Those companies "which, like the West Middlesex and Grand Junction, possess ample and efficient filtering apparatus, "were enabled so far to cope with the difficulty as to "send out their supply free from suspended matters." Towards the end of your report you state, "The West "Middlesex Company's water, though well filtered "and perfectly transparent, had been thus contaminated to an extent which would be produced by the "admixture of one-third of a gallon of average "filtered London sewage with each ten gallons of "the water. The river Lea also exhibits a very "high previous sewage contamination." Do you imagine that if those companies had proper filtering apparatus the water would have been supplied to the metropolis in a wholesome state?—It has been proved that water which is perfectly transparent to the eye still contains germs of animalculæ which afterwards develope in that water, and my remarks apply there to the appearance of the waters to the eye. The appearance of the other samples of water that were delivered by the Southwark Company on the 21st of January last, and the Lambeth Company, and to some extent by the Chelsea Company, may be judged of by this specimen of the Lambeth water which was drawn for analysis from the main on the 21st of last month (*producing a specimen*), and it is not much better this month.

6244. Then are we to understand you to say that no amount of filtration would render those waters fitted for the supply of the metropolis?—As I have stated, no process of filtration that has hitherto been devised will remove choleraic dejections from water; and inasmuch as it is generally believed that the noxious matter of sewage exists there in the form of minute germs which are probably smaller than blood globules, I do not believe that even filtration through a considerable stratum of chalk could be relied upon to free the water perfectly from such germs.

6245. Do you believe that the Thames basin could supply the metropolis with good and proper water if the supply were taken higher up the river than the point at which it is taken now?—At the present moment I have no means of judging of that satisfactorily, because there is no analysis of the sources of the Thames that I am aware of, to enable me to form an opinion.

6246. Do I correctly gather from your evidence that you think that no water that had passed over or through any cultivated district would be proper for the supply of the metropolis or other large towns?—I do think that that water is not safe for human consumption afterwards.

6247. That being your idea, would not it follow that no water could be supplied to the metropolis in a wholesome state from the Thames basin, because the whole of the Thames basin is as we all know very considerably cultivated?—Yes, I think it is very likely that that would be so; and inasmuch as the chalk water from shallow chalk wells exhibits this previous sewage contamination, I should infer that the springs feeding the Thames would also exhibit that contamination; but that does not necessarily follow, because it is stated that the deep chalk wells furnish a water free from nitrates and ammonia, or very nearly so, and consequently they are not so contaminated.

6248. Do you think then that there is a point below which the sewage matter would not get down?—At all events there is a point apparently below which the skeleton of the sewage no longer finds its way, it is either consumed by some living organisms and converted into other forms of matter, or it is absorbed by the strata themselves through which it passes. I have not myself analysed the waters of the deep chalk wells, but Mr. Dugald Campbell has done so, and he states that they are free from nitrates.

6249. The sewage which you allude to I presume would be the manure which the land would be subject to where a great quantity of stock was kept upon the land?—Yes, the drainage from such land I should consider unsuitable for a water supply.

6250. Would not that rather lead to the conclusion that you could get no water except in those very deep chalk wells, unless from a district where there is little or no population?—Yes, it would certainly lead to that conclusion.

6251. If I understood you aright yours was merely a general proposition, that if water was contaminated with sewage it would be unwholesome for domestic use for the purposes of the inhabitants of the metropolis, inasmuch as you find in these various waters the nitrates which you deseribe as skeletons of sewage?—Yes, because there are no processes by which the sewage contamination can be effectually removed on a large scale, my opinion is founded upon that.

6252. That is the conclusion that you have arrived at from the general state of things with regard to the waters; but is it a fact that the health of the metropolis is in any degree injured, or that there is any amount of disease caused by the water?—I think there have been some very notable instances of that kind. In the cholera outbreak in the year 1849, and again in 1854, we had evidence from Dr. Farr in the reports of the Registrar General that great mortality prevailed in those districts which were supplied with Thames water that was largely contaminated with sewage.

6253. You are probably of opinion that the use of water largely contaminated with sewage in districts which were very closely populated and where there was an absence of air and cleanliness, would tend to produce cholera; but speaking now of the water that is generally supplied throughout London, not in any particular district where the water is known to be contaminated with sewage, either by soakage going into some particular well or otherwise, do you trace any disease consequent upon that?—I have gone carefully through the evidence with regard to the connexion between the outbreak of cholera in the East of London on the recent visitation and the water supplied by the East London Company, and I have come to the conclusion that there was a direct connexion between the water supply and the outbreak of the disease in the eastern portion of London.

6254. In the East London water the mean of nitrates is according to your table ·132, is it not?—

Yes, that is for the whole of last year; it has been wonderfully improved since that outbreak occurred.

6255. And the mean in the water of the New River Company being ·221, and in the Chelsea Company ·192, there was consequently in those waters of the New River Company and the Thames water a greater amount of the skeleton of sewage than in the East London water?—There was, taking the whole of last year.

6256. But in those districts supplied by the New River, and the West Middlesex, and the Grand Junction companies, there was less cholera, was it not?—Yes, but this analysis did not extend back to that time.

6257. But if that is so, would not it seem probable that the cholera was attributable to other causes than the water, inasmuch as according to this analysis the water in those two districts supplied by the New River Company, and by the Chelsea, West Middlesex, Southwark, and Grand Junction companies, is a worse water than what you describe as having caused the cholera?—At the time of the cholera outbreak, the water delivered by the East London Company, as determined by chemical analysis, was rather worse than any other water delivered in London, but not very remarkably worse. Before the cholera outbreak of 1866 the water delivered by the East London Company from the Old Ford reservoir had never been analysed by me. The monthly sample of the East London Company's water had, prior to August 1866, always been taken in Shoreditch, which is supplied from Lea Bridge.

6258. Then if the deduction which you draw is a correct one, that it was attributable to the water, the other districts ought to have been equally visited?—I think not, because there was a special reason why this East London water should have been particularly contaminated at that time. There exist two open reservoirs near the supply reservoir at Old Ford, and those open reservoirs were filled by filtration through a bank of gravel with water from the river Lea. It has been proved in evidence before Captain Tyler that this water in the uncovered reservoirs, which was ostensibly kept there for emergency in case of fire, was regularly, or I should rather say irregularly, according to the demand, mixed with the filtered water which was sent out from Old Ford; and it was so mixed a few days before the outbreak of cholera in the East of London. There was a sluice which permitted of this water in the uncovered reservoir being allowed to flow uninterruptedly into the covered reservoir; again this covered reservoir at Old Ford is situated in a porous soil, or one-half of it at least is porous, and very much saturated with sewage. And it was also proved in that inquiry conducted by Captain Tyler that a good deal of soakage of foul water from the surrounding soil made its way into this covered reservoir, from which the best quality of water distributed from Old Ford was sent; so that there was a special cause of contamination in that water, over and above the general contamination which was common to the whole river supply of London.

6259. You have spoken as to the properties of the London water with regard to health; what is your opinion as to the effect upon health as between hard water and soft water?—My opinion is that there is no difference.

6260. You mean, of course, provided it is free from sewage contamination?—Yes.

6261. With regard to their use in manufactures, what is your opinion?—There is a great advantage in the use of soft water.

6262. You are acquainted, I presume, with Dr. Clarke's process for softening water?—I am.

6263. What is your opinion of it?—It is a beautiful process, and comparatively a very simple process, but I believe that it could never be carried out for the softening of such vast volumes of water as are required for the supply of London.

6264. The Commission have had laid before them a piece of lead (*handing the same to the witness*), and it has been stated that its appearance is the effect of Dr. Clarke's process; will you state what your opinion is with regard to it?—I should think that this effect has been produced upon the lead by some very special circumstance. It appears to me that there has been a piece of mortar, or a piece of lime, or something of that kind, upon each place where the lead is eaten into. It is obviously not uniformly attacked, and it is well known that lime or mortar placed upon lead will induce a rapid corrosion of the lead upon the place where it falls. And the cause of this is quite evident; the lime abstracts from the water the carbonic acid, which is usually the protecting material, which most effectually prevents the London water, for instance, from acting upon lead; but if this carbonic acid is removed by the lime or the mortar, then the oxygen dissolved in the water, and which is not so removed by the lime, affects the lead, and a rapid corrosion at that point takes place.

6265. What effect has soft water upon lead?—Soft water is much more liable to act upon lead than hard water, but we have many cases in those waters which have been examined by my colleague and myself for the Commission, of very soft water not acting in the least upon lead, even upon bright lead, so that there is no necessary connexion between the softness and the action upon the lead.

6266. Does the London water, which we call a hard water, become soft by boiling?—If it be boiled for half-an-hour it is softened very considerably.

6267. What would the difference be between two given portions of water, taking either the Lake water or the Welsh water, and the London water, and boiling them both the same period, what would be their condition at the end of that time, would they retain their proportionate degrees of hardness, or would they both be at the expiration of the time equally soft?—Not quite equally soft. The Welsh and Cumberland waters would be very much in the same condition at the end of the boiling as they were at the beginning; the London waters would be reduced to about four or five degrees of hardness by that circumstance, and would therefore still be harder than the Welsh and Cumberland waters, but not much harder.

6268. Then would boiling the London water cause it to lose from nine to ten degrees of its hardness?—It would.

6269. Have you given your attention at all to the advisability of a constant supply, or do you confine yourself only to chemical matters?—I have thought a great deal about it, and I have had experience of both systems of supply for a considerable length of time. I was for more than six years a resident in Manchester, and was supplied there upon the constant system with very soft water, and I have since resided 10 years in London, and have been supplied upon the intermittent system with hard water; and although I cannot complain of the amount of water which is now delivered into my cisterns in London, still there are times when we are short of water, and have to apply to the turncock to grant us a special supply, and I must say that this is always done with the greatest readiness when such an application is made. But with regard to the deterioration of the water by storage in cisterns and in tanks, I think that too strong an opinion can scarcely be expressed. In my own house, when I first went to it, I found that the waste pipe from the cistern which was to supply us with water was not furnished with a trap at all, but that there was free communication between the sewer and the interior of my house through this pipe, and sewer gases were brought just upon the surface of the water in the cistern, and I believe that is the condition of most of the houses around me at Haverstock Hill. I had this pipe trapped in the ordinary manner by bending up the end of it so as to form a loop in which the water lodged; but inasmuch as the companies will not allow, if they know it, the water to rise in the cistern so that an overflow should take place through the waste pipe, this water which seals the waste pipe gradually evaporates, and in the course of two or three months there is again the same free

Dr. E. Frankland, F.R.S.

27 Feb. 1868.

communication between the drain and the interior of the house, and on many occasions I have found this to be the condition of things. At the present moment I am having the waste pipe removed, and having a self-acting valve placed which is to act by means of a floating ball to replace the waste pipe, so that there can be no further contamination of that kind.

6270. (*Sir J. Thwaites.*) Does water absorb the gases which are generated in the sewers?—Water will absorb the gases readily. I do not, however, attach very much importance to the mere absorption of gases; but those gases from sewers in all probability contain also floating in them organic germs, and it is those which, when conveyed into the water in this way, are productive of mischief afterwards.

6271. (*Mr. Prestwich.*) The result of your analysis shows, does it not, that those Welsh and Cumberland waters contain but a very small quantity of solid impurities?—A very small quantity.

6272. Those samples of water were taken during the months of May and June. Have you any reason to believe that those solid impurities would vary according to the season of the year?—I think they probably would, but within comparatively narrow limits. I think if you refer to the analyses made by Mr. Way of those waters that were taken in the winter months, you will find that the total solid impurity is somewhat in excess of that which is given in our analyses, markedly in excess, but still the additional quantity is not very great.

6273. In your experience with regard to the Loch Katrine water, have you found there any variation from month to month throughout the year?—I have only examined the Loch Katrine water once, and that was a sample taken, I think, in the month of February last year.

6274. Of what do the solid impurities in the waters of the two districts of Wales and Cumberland consist?—They consist, in the first place, of certain mineral matters, of which the following are the principal, namely, lime, magnesia, potash, soda, sulphuric acid, silica, chlorine, small quantities of nitrates and nitrites, and small quantities of ammonia; and, secondly, organic substances.

6275. With regard merely to the mineral contents, what would be the proportion of carbonate of lime?—The proportion of carbonate of lime is with very few exceptions remarkably low. In our analyses we get the results in parts of lime, not of carbonate of lime; but if you multiply those results by $1\frac{3}{4}$ you get very nearly the quantity of carbonate of lime—thus the Severn water is represented as containing ·417 of lime, which would be about ·745 of carbonate of lime in 100,000 parts of water.

6276. It shows, therefore, a permanent difference between those waters and the London waters of some 10 or 15 degrees of hardness?—It does.

6277. For drinking water you say you attach no importance to that difference of degree of hardness?—Not as regards its effect upon health, but I attach great importance to it in the use of water for cleansing purposes.

6278. Apart from the degree of hardness, in searching for water for the supply of a town what should you be most careful in avoiding, having reference to the health of the population?—In avoiding a water which had ever been contaminated with sewage or manure matter.

6279. You stated, did you not, just now that the previous contamination, so far as it had ended in the formation of nitrates and nitrites, was of no importance?—That portion of the sewage which has been converted into nitrates and nitrites is of no importance.

6280. Therefore generally that might be left out of the question also?—Yes, so far as that itself is concerned.

6281. Apart from those two elements of consideration, what should you consider the substance to avoid?—In any water nitrogenous organic matter would be a substance to avoid.

6282. It appears in the analysis which you have given of the water from Wales and from Cumberland, as compared with the London waters, that the organic nitrogen is the lowest in the latter; that is a substance, I presume, which it is of chief importance to avoid in water?—Yes, it is.

6283. You say in your table that the mean of organic nitrogen in the water delivered by the Chelsea Waterworks is ·011?—Yes.

6284. And the mean in the water of the River Lea Company is ·002?—Yes.

6285. And the chalk water from the Kent Company is as low as ·001?—Yes.

6286. I see further that you give the mean of Loch Katrine water as ·008?—Yes.

6287. And in the water supplied to Manchester it is ·026?—Yes.

6288. And the water supplied to Lancaster is the only one which reaches the low quantity of the Kent Company, both being ·001?—Yes.

6289. And it appears that those waters from the Welsh district show means of ·006 and of ·004, whilst Bala lake gives ·001. Therefore it appears by this analysis that there is no superiority in the waters from the Welsh and Cumberland districts over the London waters, as far as regards the presence of organic nitrogen?—As far as regards merely the presence of organic nitrogen there is not, as I have in fact stated in my report, any ground for selecting the one in preference to the other; but if we take into consideration the nature of the organic substance of which this organic nitrogen forms a part, there is a considerable difference I find between the organic nitrogen in the waters at present supplied to London and the organic nitrogen in the waters of the two proposed districts, and this difference lies in the proportion between the organic carbon and the organic nitrogen in the three cases. In the case of the two proposed districts, the proportion of organic carbon and organic nitrogen, that is, of nitrogen to carbon, varies in the strongly peaty waters between 1 to 13 as the maximum, and as the minimum 1 to 95; that is to say, in the waters which are distinctly peaty waters in the two districts of Cumberland and Wales, which contain a considerable proportion of organic nitrogen, the proportions vary between those limits, namely, 1 to 13 as the maximum, and 1 to 95 as the minimum. I have found that the relation between the nitrogen and the carbon in the organic matter present in sewage varies between 1 to 3 as the maximum, and 1 to 5 as the minimum. Therefore, there is a larger proportion of nitrogen in the organic nitrogenous matters present in sewage than there is in the organic nitrogenous matters present in the peaty substances with which water is contaminated. The proportion existing between nitrogen and carbon in some of the London waters I have calculated out. In the sample upon the table which came from the Lambeth Waterworks, the proportion between nitrogen and carbon there is 1 to 8·8. In the Chelsea Company's water, which was in a very bad condition also last month, the proportion was 1 to 6·08, and in the Southwark Company's water the proportion was 1 to 8. I infer consequently from those numbers that the waters delivered by the Chelsea Company, the Southwark Company, and the Lambeth Company, on the 21st of last month, were contaminated with unoxydised sewage.

6290. Have you any mode by which you can distinguish the difference between nitrogen derived from animal substances and that derived from vegetable substances?—There has hitherto been no possibility of establishing such a distinction, but this relation of nitrogen to carbon in the two classes of substances, in the peaty matters which are the common contamination of what we should call comparatively pure water, and in the sewage organic matters, I believe establishes a basis from which we can ascertain what is the kind of contamination to which the water has been subjected.

6291. Would not the organic nitrogenous sub-

stances in any of those waters be liable to putrefaction in the one case in the same way as in the other?—That is a very important point in regard to those substances. I have made numerous experiments under that head which I think have a very direct bearing upon the question which you now propose to me, and perhaps I may be permitted to state the results of those experiments, which are as follow: "If the "sewage of the 600,000 persons draining into the "Thames had the strength of average London sewage "it would amount to 18,000,000 gallons daily, and if "the average flow of the Thames at Teddington be "taken at 800,000,000 gallons daily, it follows that "the river would there contain 2,250 parts of sewage "in 100,000 parts, or $2\frac{1}{4}$ per cent. Now this sewage "as it flows into the river contains at most two parts "of organic nitrogen in 100,000 parts. This would "contaminate the whole volume of the river only to "the extent of ·045 part of nitrogen in 100,000 parts "of water. On the 21st of January last the water de-"livered by the five companies drawing their supplies "from the Thames contained the following amounts of "organic nitrogen in 100,000 parts: Chelsea water, "·058; West Middlesex, ·027; Southwark, ·061; "Grand Junction, ·031; and Lambeth, ·062." The West Middlesex and Grand Junction waters were well filtered and transparent. In very numerous experiments in my laboratory I find that a mixture of sewage with nine times its volume of water well agitated every day and freely exposed to the air oxydises but to a very slight extent. Thus immediately after mixture the contaminated water contained ·267 part of organic carbon and ·081 part of organic nitrogen in 100,000 parts, whilst after 96 hours it still contained ·250 part of organic carbon and ·058 part of organic nitrogen, and even after 192 hours the undecomposed organic matter still contained ·200 part of organic carbon and ·054 part of organic nitrogen. Consequently that portion of sewage which is not decomposed in the sewers themselves, but which finds its way into the river, is afterwards decomposed with extreme slowness.

6292. Then you conclude that it is very difficult to get rid of sewage matter by running water?—I do. That portion of it which remains undecomposed after its passage through the sewers oxydises with extreme slowness. About four-fifths of the nitrogenous matter contained in fresh sewage, which has just been produced, as it enters the sewer is decomposed before the sewage, after a run of two or three miles, emerges into the river, and the remainder, I believe, as far as my experiments teach me, is decomposed with extreme slowness afterwards.

6293. Have you not shown somewhere that the sewage which has been delivered into the Thames in the higher parts of it is almost all decomposed by the time the river arrives above London?—I have. I have reported only three times upon the presence of actual sewage in the Thames water as delivered by the water companies. On two of those occasions I reported that I could not find any trace of unoxydised sewage, but I stated at the same time that my methods did not allow me to detect a smaller proportion of unoxydised sewage than one part in 1,000 parts of water. On the third occasion I found unoxydised sewage in the water of the West Middlesex Company and reported upon it, but from the explanation of the company's engineer the origin of that sewage was traced to a broken pipe, which passing over a gulley-hole, or through a portion of the street sewer, had, during the time that the water was turned off at night, become contaminated by the contents of that sewer. Those are the only three occasions on which I have reported as regards the presence or absence of actual sewage as distinguished from previous sewage contamination in the London waters. Now the proportion which is indicated here as the normal state of things would, at that period when those reports were made, have been undistinguishable in the water by the methods of analysis then at my command; but those methods have been considerably perfected during the last four or five months, and I can now detect a smaller proportion of sewage than one part in 1,000 parts of water.

6294. Can you put in those reports?—Yes, I will do so.

6295. I see in your present reports to the Registrar General you give the organic nitrogen in all cases, whereas some few months ago you did not do so?—Yes, I commenced in the month of January last to give that in the returns.

6296. Reverting to this particular question of the presence of organic nitrogen in those waters, what do you consider to be the effect upon water of the presence of organic nitrogen, whether derived from an animal or vegetable source?—As far as we know, the presence of organic nitrogen in the form of vegetable organic matter, such as peaty matter, is innocuous, unless contained in a considerable quantity in the water; but when contained in the water in the form of sewage matter it is believed to be noxious.

6297. Did I rightly understand you to say that you cannot distinguish in those cases whether it be derived from vegetable matter or from animal matter?—I have said that until recently it had been impossible to distinguish between the two, but that now I considered that the proportion between the carbon and the nitrogen in the two cases afforded a basis from which we could, in many instances, decide.

6298. That is only an indirect method?—Yes, because the analysis itself gives no difference between the nitrogen from the two sources.

6299. In the two mountain districts you have not only the possibility of the organic nitrogen being derived from vegetable matter, but as sheep are also pastured in those districts, and there are a certain number of houses and villages, a portion of this nitrogen might be derived from those sources?—Yes, it might; but I think in such a case we should trace what we call previous sewage contamination in the water, and that has only been done in a very few cases in the samples from Wales and Cumberland.

6300. Will you be so good as to refer to the column organic carbon, where it appears that the mean maximum proportion in the London waters is ·275, and the minimum is ·143?—Yes, that is the organic carbon.

6301. Is the mean the mean for the year?—It is the mean of six months, viz., May, June, July, August, September, and October 1867.

6302. The water from Loch Katrine gives ·256?—Yes.

6303. And the water at Lancaster ·157?—Yes.

6304. And the water from the Welsh district ·460 and ·289?—Yes.

6305. And the lowest is ·227?—Yes, that is from Bala lake.

6306. Showing therefore a larger quantity of organic carbon to be present in those waters than in the London waters?—Yes.

6307. That would arise probably from the presence of peaty matter, would it not?—I believe that that is the source of the organic carbon there.

6308. Do you attach any importance to the presence of it?—I think it is very undesirable that there should be a large quantity of organic carbon in the water. I think that the water from Loch Katrine very nearly approaches the limit that one would desire to go to, because if you get beyond that amount the water becomes perceptibly tinted yellow.

6309. Would not the presence in excess of organic carbon also tend to interfere with the proper aeration of the water?—I think not; not to any perceptible extent, at least.

6310. Would it not remove the dissolved oxygen?—I do not think that the organic carbon in the form of peaty matter has much effect in removing oxygen from the water. Organic carbon in a more putrescible condition would have that effect undoubtedly, but I do not think that there would be a very marked removal of oxygen by peaty matter in the water.

6311. Then there would be no natural mode of removing this organic carbon if that were the case?—The mode which is generally considered to be effi-

Dr. E. Frankland, F.R.S.

27 Feb. 1868.

cacious in removing this organic carbon is storage for a considerable time in large lakes or reservoirs, and there in all probability this peaty matter does undergo some slight process of oxidation by which it is precipitated. It is not completely burned up or oxydised, but it is precipitated there, and it necessitates the absorption probably of a very small portion only of oxygen to effect that change in it. At all events we found that the proportion of oxygen to nitrogen in those most peaty samples, even after they had stood for some length of time, was not different from that in spring water or in distilled water.

6312. You have expressed an opinion with regard to solid impurities. Have you any reason to believe that the quantity of organic nitrogen and organic carbon would vary according to different seasons in the year?—I should think it would not vary much in large storage reservoirs, but in the streams that have been analysed it would doubtless vary; in fact we have evidence that it does vary, in the difference that exists between the flood samples and the dry-weather samples collected in Wales from the same streams.

6313. Would it not be likely to differ very materially according to the state of the vegetation at different periods of the year?—I scarcely think that vegetation would have much effect upon this kind of organic matter in water, that is to say, upon peaty matter in water.

6314. Is not Loch Katrine water found to vary; is it not sometimes much more peaty than at other times?—I have heard it stated so, but I have never seen an actual analysis showing that difference; it may be so, and probably is so.

6315. With regard to the estimated previous sewage contamination, to which you attach considerable importance, how do you consider the nitrates and nitrites to be produced?—I consider that the nitrates and nitrites are produced by the oxydation chiefly of ammonia, the ammonia being derived from the urea present in the sewage. The urea is the first thing to decompose in sewage, and it is the form in which the greater part of the organic nitrogen in sewage is contained. This urea decomposes before the sewage leaves the sewer, in most cases, and hence it is that sewage flowing from the mouth of a sewer contains, comparatively, so little organic nitrogen, not more than one-fifth of what average sewage contains in combined nitrogen altogether.

6316. There is no doubt that that is one source of production, but are there not many others?—Yes, the oxydation and gradual transformation into mineral compounds of organic bodies containing nitrogen which are capable of that transformation. In all those cases where bases such as carbonate of lime are present in water the nitrogen takes the form of nitric acid and nitrous acid, and combines with those bases.

6317. Might not a large proportion of those nitrates and nitrites be derived from the soil?—Yes, from the manure of the soil.

6318. But might it not be derived from soil which has not been manured?—I think not, because soil which has not been manured at all contains, so far as we know, organic nitrogen in the shape of peaty matter, or *humus*, which is much the same thing; and judging from the composition of the water which we have analysed from those large lakes, that kind of nitrogenous organic matter does not pass into the condition of nitrates and nitrites, in other words, does not completely oxydise with sufficient rapidity.

6319. One source of ammonia would be, I presume, the ammonia which falls with the rain?—Yes, in rain water you have both ammonia and nitrate of ammonia and nitrite of ammonia; an allowance is made for the maximum quantity of those substances ever found in rain water, and that is deducted from the number from which this previous sewage contamination is estimated.

6320. Have any experiments been made in this country with regard to the quantity of nitrates and nitrites contained in soil which has not been manured?—Not as to the quantity contained in the soil, but I have already given the results of analyses made of water draining from such a soil. Where the soil has been drained by drain pipes, the water flowing from those drain pipes has been analysed by Mr. Way, the result of which I have already given; it indicates some small amount of previous sewage contamination—I mean small in comparison with water from manured and arable land.

6321. Messrs. Gilbert and Lawes have made a great many experiments, have they not, upon the quantity of ammonia in rain?—Yes.

6322. Supposing that the soil contains nitrates and nitrites, from whatever cause, I presume that the streams flowing from that district would be liable to contain those salts in solution?—Yes; nitrates and nitrites are readily washed out from soils, as has been shown by Mr. Way; consequently rain water draining through those soils would dissolve out any nitrates or nitrites which they might contain, and if a nitrate had been applied as a top dressing to the soil, a good deal of it would be carried out in that way undoubtedly.

6323. Are you aware of the experiments which have been made in France upon soils taken from the Vosges mountains and other districts which have never been manured, and are perfectly free from any cause of contamination of that sort, but which show the presence of nitrates in considerable quantities?—No, I have not seen the results of those experiments.

6324. Were you aware that some experiments were made a few years ago by Mons. Boussingault with soil taken in a forest of fir trees at an elevation of some thousand feet above the level of the country, and that in that soil he found a considerable quantity of nitrates?—I was not aware of those results; they are interesting in connexion with this subject, and I presume that that soil had not been, practically, at all events, manured by any considerable number of animals in the forest.

6325. No; it was just as the soil would be upon the Welsh or Cumberland hills—it had never been manured and never disturbed. Experiments were also made upon soil taken in the forest of Fontainebleau and various districts which really never had received any manuring, and yet they showed a quantity of nitrates as large in some cases as soil taken from meadows and taken from arable land?—That may be so, but that must be a condition of things which is very different from the condition that obtains in the Welsh and Cumberland districts, inasmuch as the washings from those soils in those districts contain a scarcely appreciable quantity of nitrates. I mean the washings as represented by those waters which have been collected.

6326. Might not that arise in some measure from the extremely rainy character of the district?—Yes, it might.

6327. And the salts in the other cases from the decomposition of vegetable matter probably?—Yes, probably that might to a certain extent come into play.

6328. If such be the case, it would seem that you could not very well refer the presence of nitrates and nitrites in all waters exclusively to previous sewage contamination. Without contesting that that may in many cases be so, are there not other causes in operation which may have produced the same result?—There are, undoubtedly, causes which will produce a result of that kind to a certain extent. We have the presence of those materials, as I have already mentioned, in rain water, and it is conceivable that rain water falling upon a very dry sandy district, and evaporating there mostly from the surface, might leave those nitrates behind, and they might accumulate there to some extent from that source, and they may also be produced by the decay of purely vegetable matter. This strict analysis of water for nitrates is comparatively a new thing, and it is possible that we may find sources of those nitrates which we are at the present moment not aware of. But it is a remarkable circum-

stance that waters which it is well known cannot be contaminated by manure or by sewage, never do contain those nitrates in a proportion bringing them near to the point of previous sewage contamination.

6329. Might not those nitrates also be produced by nitrogen derived from the decay of vegetable matter as well as from other sources?—I presume that they could be derived from the decay of some kind of vegetable matter, but as I have just said, I do not think they can be derived from the decay of peaty matter, because we do not find them in districts where peaty matter prevails. Where peaty water is stored for a length of time in lakes, we should expect to find in the water of those lakes a considerable proportion of nitrates, if the nitrogen in that peaty water were converted into that form of combination.

6330. But are there not plants and vegetables which contain a considerable quantity of nitrogen?—Yes.

6331. Am I to understand that you admit the possibility of those nitrates being derived from other sources than that of sewage and animal matter?—I admit the possibility of such a thing, certainly, because vegetable matters contain albumen for instance, and I can conceive that albumen in this process of decay and decomposition will give rise to nitrates, nitrites, and ammonia, but that, in this country at all events, this process goes on to any great extent, I do not believe.

6332. Still from the presence of nitrogen in rain water, and in some vegetable substances, you admit the possibility that nitrates might have a vegetable as well as an animal origin?—Yes; I admit the possibility, and I distinctly allow for the nitrogen in rain water. In all determinations of previous sewage contamination, it is not merely admitted, but always allowed for.

6333. There is another source of nitrates which I should like to ask you a question upon. Do you know what results the analyses which have been made of chalk or some of the marls or oolites give, whether they show the presence of nitrates?—If the question refers to dry chalk, I have not seen those analyses, but I can readily conceive that there may be a considerable quantity of nitrates present in chalk under such circumstances.

6334. I would refer you to the same authority, Mons. Boussingault, who made some experiments upon the chalk at Meudon, near Paris, and upon some of the marls in other parts of France. In the chalk at Meudon he found a certain proportion of nitrates, and again in the marls he found a still larger quantity, but it was not of constant occurrence?—There have been recently some important investigations made by Mons. Béchamp on the condition of chalk, even taken from great depths, and Mons. Béchamp believes that he has proved that chalk is full of living organisms, that is to say, organisms living at the present moment; at all events, he certainly has proved that chalk can act as a ferment, and can convert sugar into butyric acid, a process which we have very strong reason to believe, after long researches, can only be accomplished through the intervention of living organisms.

6335. Would not therefore the presence of nitrates in chalk or in certain soils account sometimes for its presence in streams and springs?—Yes, and I would not at all distinguish in a sanitary manner between nitrates derived from putrefying animal matter, such as dead dogs, for instance, and nitrogen derived from the putrefaction of manure or sewage. I think, so far as our knowledge extends, that the deleterious character of the waters containing any of those matters in solution is pretty nearly equal. If the chalk, for instance, contains a vast number of living organisms, it is conceivable that those organisms in their decay may give rise to quantities of nitrates and nitrites and of ammonia, and it may be that some of those matters found in the chalk water are derived from this source; but I would not on that account think that a water was preferable because it had been only in contact with putrefying animalculæ rather than in contact with putrefying sewage.

6336. You are assuming, are you not, that there is putrefying animal matter in the chalk independently of sewage, a position which has not been at all proved?—We know that sugar can be converted into butyric acid by bringing it into contact with putrefying cheese, and we now know that it can be equally converted into butyric acid by bringing it into contact with chalk, therefore the inference is very strong, although I am ready to admit that it is not absolutely conclusive.

6337. How could the animal matter in the chalk have been derived. Any of the organisms originally present in the chalk would no longer supply nitrogen in that form?—No; the nitrogen supplied to these living animals could only be derived, as far as I am aware, from nitrates and nitrites of ammonia contained in the rain water falling upon the chalk, in the first place; and secondly, from nitrates and nitrites in the drainage water subsiding into the chalk from the surface; but I think that those two would be available sources for the acquisition of nitrogen by such organisms. So far as we now know those organisms are not capable of assimilating elementary nitrogen as it exists in the atmosphere.

6338. Do not springs, although away from all sources of sewage contamination, frequently show the presence of nitrates?—I have never yet found an instance of such a spring. I have examined several springs which have been very noted for the water which they deliver being very palatable, and I found in those springs quantities of nitrates and nitrites; but I found that those springs derive their water from manured land, in all cases where I have found those nitrates and nitrites, but I have investigated spring water only to a slight extent.*

6339. I may mention that the same authority gives instances of springs away from all such sources of contamination, yet containing a considerable quantity of nitrates?—I am not aware of any such case, but perhaps I may mention in connexion with this matter that the quantity of nitrates and nitrites existing in some of the well waters of London is shown by the analyses of Dr. Letheby. There is a pump in Aldgate which exhibits a previous sewage contamination amounting to 38,080 parts out of every 100,000 parts.

---

* Since the above answer was given I have analysed a sample of spring water issuing from Mother Ludlaw's cave, which supplies Mr. Bateman's house at Moor Park, near Farnham. The spring issues from the far end of a deep cave, from a cleft in the lower greensand rock, and is fed by the water falling on a heather-covered barren moor, and filtering through the sand several hundred feet in thickness. The following are the results of the analysis:—

	In 160,000 parts of water.
Total solid residue	4·55 parts.
Organic carbon	·030 ,,
Organic nitrogen	·010 ,,
Nitrogen as nitrates and nitrites	·034 ,,
Ammonia	·001 ,,
Total combined nitrogen	·045 ,,
Previous sewage contamination	·30 ,,
Hardness	·7 ,,

We have, therefore, here an example of a spring water which has been extensively in contact with peaty matter, but which exhibits only a mere trace of previous sewage contamination, and which is in several respects superior to both the Welsh and Cumberland samples. I have also referred to the results of M. Boussingault's analyses of spring water, quoted by Mr. Prestwich, and find that out of 21 samples analysed 10 were perfectly free from previous sewage contamination. On the other hand, the spring forming the source of the But at Montmartre in Paris had a previous sewage contamination of 85,310 parts in 100,000. It may also perhaps be worth while to give the following estimations of previous sewage contamination, calculated from M. Boussingault's analyses:—

	Previous sewage contamination in 100,000 parts.
Artesian well at Grenelle	0
Source of the Presle, Eastern Pyrenees	0
The Rhine at Bâle	0
The Nile	700
The Seine at Notre Dame	1,200
The Ourcq—supplied to Paris for street watering and ornamental purposes	1,910
Well in the Rue Traversine, Paris	299,780

Dr. E. Frankland, F.R.S.

27 Feb. 1868.

This water has been in contact with an amount of decaying animal matter which would be represented by the decaying animal matter in 38,080 parts of average London sewage. The pump in the Heralds' College yard exhibits a previous sewage contamination of 63,620 parts. The one in Leadenhall Market, 57,370. The pump in the Minories, 57,060. The one in St. Nicholas Olave churchyard, 75,640, (and this brings us into contact with another source of nitrates, namely, the putrefaction of animal remains, the remains of actual flesh and blood,) and the pump in the Guildhall Buildings, 5,140 parts.

6340. All those are from sources, are they not, where there would be every probability of the presence of animal organic matter in considerable quantities?—Yes.

6341. Therefore that is where you would expect to find a maximum quantity of nitrates?—Yes; that is in fact what has confirmed the original notion that I formed on this matter, that where such contamination is very obvious there we find it to a great extent, and where such contamination cannot be supposed to exist there we do not find it. But if there are springs which have been examined and which are free from animal organic contamination, and yet exhibit nitrates and nitrites amongst their constituents, I am quite free to admit that those would be cases certainly which would throw some doubt upon this proposition.

6342. In the cases which you have just quoted would not the quantity which you give here for the Kent water, namely, 3,393 parts of previous sewage contamination, be out of all proportion if you ascribe it entirely to such a source?—I think not. I should rather be inclined to expect more than that, and I believe that there would be more than that if it had not filtered through a very extensive stratum of chalk, because in the analyses of water which has drained through cultivated land we find, as I have already stated, an average sewage contamination of 20,370, and through unmanured pasture land, 830. You are aware, and are much better able to judge than I am, of the extent to which the water which collects in the chalk percolates through arable and manured land, or percolates through unmanured land. I spoke to Professor Ramsay upon the subject a short time ago, and he considered that the great bulk of the water would pass through cultivated and manured land into the chalk, and in that case we should rather expect a greater amount of sewage contamination, inasmuch as the average sewage contamination in water running from the drains of manured land is 20,370, and here we have only between 3,000 and 4,000.

6343. But a large portion of that would pass into the streams of the district, would it not?—Those waters that I give here are waters which do not in that way pass into the streams of the district, but which have soaked through the soil and run out of the drain pipes.

6344. Where you would have the maximum amount of contamination?—Yes. I suppose that which would run over the surface into the streams of the district would probably contain less of the nitrates.

6345. The proportion of nitrates and nitrites appears to be tolerably uniform whether you take the water from the New River Company or whether you take it from the Thames?—There is no very substantial difference between the previous sewage contamination of the Thames and of the New River; but there is a very substantial difference between that of those two rivers as compared with the water from the chalk, the Kent Company's water, and still more as compared with the water which is pumped at Grays by the South Essex Company. The contamination is about three times as great in the chalk water pumped at Grays as it is in the case of the Thames water or in the water of the river Lea.

6346. Is not the water from the spring at Grays more likely to be removed from any sources of sewage contamination than either of those other waters?—I am not so sure of that, because the whole of the sewage from London passes into the Thames at a point considerably above Grays, and there is some evidence of communication between the bed of the Thames and the water in the chalk. This has been traced with very considerable probability in the chalk wells in the Woolwich Arsenal by Mr. Abel; so that if we are to assume that there are any fissures in the chalk through which the Thames water can make its way into those wells of the South Essex Company, that in itself would account for a good deal of this previous sewage contamination.

6347. The Thames water at Grays is brackish water, and the spring would show the presence of chlorides, would it not?—I have never estimated the exact amount, but it contains a considerable quantity of chlorides.

6348. But not more than other chalk waters around London?—I am not aware.

6349. Do you trace any connexion between the previous sewage contamination in those cases and the organic nitrogen actually present in the waters?—Not necessarily. On the contrary, probably the amount of organic nitrogen present in a water is in the case of those waters which are supplied to London generally almost inversely as the quantity of previous sewage contamination exhibited by the water, because chalk waters are remarkably free from organic nitrogen.

6350. According to the table of analyses in the report which you have made to this Commission, those waters which contain the least organic nitrogen contain the largest quantity of nitrates?—They do; but those waters have been filtered through chalk; at least we may presume that they have to a certain extent been filtered through chalk.

6351. In the case of those Thames waters where you have found the greatest evidence of what you consider previous sewage contamination, should you not expect to find also the greatest actual impurity arising from sewage matters?—That would depend upon the efficiency with which filtration had been performed upon those waters. Referring to my report for the last month upon those waters, you will find that the Lambeth Company's water and the Southwark and Vauxhall Company's water contain by far the largest quantity of organic nitrogen. The Lambeth water, a specimen of which you have upon the table, contained ·062 part of organic nitrogen in 100,000 parts, and the Southwark and Vauxhall Company's water ·061. Those waters were very turbid. The Chelsea Company's water was also turbid, but less so than the two samples to which I have just alluded, and that contained ·058 part of organic nitrogen. On the other hand, the West Middlesex water was perfectly transparent, and it contained but ·027. The Grand Junction water was also transparent, and it contained ·031. It is therefore evident that the organic nitrogen in those waters is to a considerable extent contained in the form of suspended matter which is removed by filtration.

6352. Some difference exists, does there not, in the opinion entertained by medical men and chemists with regard to the effect on health of soft and hard waters?—There has been some difference of opinion on the subject, but I think the general impression now is that there is not much to be said upon that point, that they are equally good as regards their effect upon health.

6353. Are one set of waters likely to be freer than the other from the growth of vegetable substances or absorption of gases?—Hard waters will not absorb gases so readily as soft waters; but if the question relates to the absorption of sewer gases, for instance, I do not think there is the same amount of difference with regard to danger from the absorption of those gases, because, as I have said before, the noxious qualities of those gases probably reside in suspended solid matters which are carried along with the gases, and those would be equally absorbed by both qualities of water, although the gases themselves would be much more readily absorbed by a soft water.

6354. It has been supposed, has it not, by some persons that a certain quantity of carbonate of lime is desirable in drinking waters, with a view to the forma-

tion of bone, but that I presume is now not at all insisted upon, because it is perfectly well known that the lime can be derived from a number of other substances. Therefore that is perfectly immaterial?—I think it is quite immaterial from that point of view. There have been opinions advanced that hard water is productive of calculous concretions, and Mons. Belgrand in discussing the water supply of Paris mentions as a notorious fact that the people of hard-water districts suffer very much from carious teeth; but I think that those are things which are exceedingly difficult to prove, and the imagination may have a good deal to do with the opinion.

6355. Have you any reason to suppose that hard water as drinking water might exercise, not any direct influence in the way of supplying carbonate of lime to the body, but in taking away less organic or mineral matter from the body than soft water?—I have never considered the subject from that point of view, I confess; but the quantity of matter dissolved in the hardest water ever used for drinking purposes is such a very small fraction of the total solvent power of the water, that I should not imagine that there could be any substantial difference between the two kinds of water in that respect.

6356. Have there been any experiments upon that point?—No, not that I know of.

6357. You expressed an opinion just now with reference to the relative merits of hard and soft water in manufactures?—Yes; I think that for manufacturing purposes there cannot be the slightest doubt that soft water is very much preferable.

6358. To what extent do you apply that rule, as a general rule or in particular cases?—I think it applies in almost all cases. I believe that in dyeing operations there are some particular styles of work, as the dyer calls them, some particular tints in madder colours for instance, which can be better brought out by a chalky water, and some dyers are in the habit of actually putting chalk into the water that they use for the purpose of dyeing those particular tints. But those are exceptional cases, and possibly also are grounded rather upon habit in particular manufactories than upon any well-ascertained fact.

6359. Are you aware that Amiens and Lyons, which are two chief seats of the dyeing manufacture in France, the one of silk and the other of carpets, are both situated in districts where the waters are hard, the one in a chalk district and the other in a district of calcareous marls and limestones?—I think that probably the case may be very similar in dyeing to what it is in the case of brewing tea. It is generally held that soft waters make better tea than hard waters, but I do not think that, as an abstract proposition, that is the case. I think that both waters are capable of making equally good tea, but the difference depends upon the length of time that the brewing is conducted. A hard water requires to be longer in contact with the tea at an elevated temperature than a soft water does, and there may be some influence of that kind in dyeing, so that by prolonging the operation you get an equally good result, and it may be perhaps in some cases a better result from hard water than you can get from soft water.

6360. What is the case with regard to brewing?—With regard to brewing, the case I think is this, that where you want to brew a pale ale it is absolutely necessary to have hard water, and not merely hard water but water that is permanently hard, that is, water which contains sulphate of lime; but in brewing any other kind of ale, where the colour is not of importance, probably soft water is best to be used as extracting a greater amount of matter from the malt.

6361. With regard to the use of water in making tea, you have expressed your opinion that both hard and soft water may be used with pretty nearly equal advantage, but that the brewing of tea requires much longer time with a hard water than it does with a soft water; is not the flavour of the tea more delicate when made from a moderately hard water?—I do not think it is if the brewing be sufficiently rapid in the case of soft water. I have experienced that during my residence in Manchester and also in London. In brewing tea with the London water, which I suppose would probably be softened down to six or seven degrees of hardness, or seven or eight degrees at all events, if the boiling has been continued for half an hour, the length of time during which the tea ought to be brewed to get the most delicate beverage is not more than five minutes, and therefore with a very soft water like that supplied to Manchester it ought not to be more than two minutes. In fact I remember that the best tea was obtained there by pouring the water on to the leaves and almost immediately off again. If you allow a soft water to remain upon the leaves for 10 or 15 or 20 minutes you get a bitter principle out of them, which is unpleasant to me, although I believe it is pleasant to some tea drinkers. Some tea drinkers think that kind of tea the best, and that is more easily got out by soft water than by hard, and therefore from that point of view it might be said that the tea would be more likely to be spoilt by hard water than by soft.

6362. With regard to the relative merits of soft water and hard water in washing, in the consumption of soap, you are of opinion, are you not, that there is great advantage in the use of soft water?—Yes, I believe that in that respect there is a very decided advantage, not merely from an economical point of view but even perhaps from a sanitary point of view, inasmuch as a thorough cleansing of the skin I believe to be entirely impossible with hard water. The decomposition which takes place between the soap and the hardening ingredients of the water produces an insoluble material, which is actually precipitated within the pores of the skin, and to some extent at all events blocks up those pores, and does not leave the skin in a clean condition.

6363. Are you speaking now of water of a moderate degree of hardness, like the Thames water?—Yes, I never wash in the Thames water if I can help it without softening it by the addition of soda to it, on that account; I always add a few grains of soda to the water before washing.

6364. Does not a good deal of the preference which may be given in that respect to the one or the other depend upon custom?—No doubt something depends upon custom, but still I think that the curdy matter which is formed in washing with London water with soap must be unpleasant to everybody; a scum floats upon the surface when you are washing with hard water which is never formed upon a soft water.

6365. But after the first effect of it has passed away, does not the water become softened by the continued operation of washing?—That I believe to be rarely or never accomplished in ordinary ablutions, the quantity of soap that you require to add to the water to accomplish that would be too great; you would get such a mass of this scum floating upon the surface as to render washing in that water which had been thus softened by soap alone a very difficult operation. I think the water always remains hard to the end of the process of washing.

6366. Have you made any direct experiment upon that?—Yes, I am sometimes compelled to wash in this hard water; if it is cold you cannot soften it. You require to have it warm in order to soften it, and I always find at the end of washing that the water is as harsh and grating to the skin practically as it is at the beginning.

6367. But it is only by feeling that you judge of that?—Only by feeling, I have never actually experimented upon it.

6368. You have I presume seen various estimates of what might be the saving if soft water were used instead of hard water?—Yes.

6369. Do you think that those estimates are as generally correct, or do you consider them as rather in excess?—I think that there ought to be considerable latitude allowed in them. I do not think that the estimate would be correct as regards the amount of soap used in personal ablution, for the reason which I have just now mentioned. It is somewhat different in the case of washing linen. Supposing that the water were

Dr. E. Frankland, F.R.S.

27 Feb. 1868.

not softened with soda, then I believe that the estimate would be correct, because you must get the whole of the lime salts precipitated in the water before this washing of the linen can be effectually carried out.

6370. (*Sir J. Thwaites.*) If I rightly understand your answer with reference to the river Thames, it is to this effect, that by reason of the large amount of sewage that finds its way into the river it is rendered unfit for domestic use?—Yes, that is so.

6371. And when once sewage finds its way into the river, it is very difficult to say where it will end?—It is very difficult to say; in fact, it is impossible to say that that sewage is ever got out of it again.

6372. Then you do not accept the theory that sewage discharged at point A, and travelling down the river, is so oxidised as it passes a distance of six or seven miles, and is so entirely destroyed that its original elements are not to be found, but it is converted into some other substance or substances which are not detrimental to human health?—I believe that that is by no means a generally true proposition. I believe that under favourable circumstances, that is, when the water is warm, and there is a large volume of water, and the water is a good deal agitated in its course, that effect may be produced so far as regards the dead organic matter in the sewage, but not at all as regards the living germs that may be present in that sewage. To illustrate what I mean, I will say that if you were to break an egg and beat up the contents, and mix them with Thames water at Oxford, the organic matter so introduced into the Thames might under favourable circumstances and probably would be entirely destroyed and converted into mineral matter before it reached Teddington; but if you were to throw an egg in without being broken, it would be carried down by the stream and would reach Teddington with its vitality undestroyed. That is an extreme case, but I imagine the same kind of thing to take place with regard to the unorganized portion and the organized and living portion of organic matter in sewage.

6373. Then is it your opinion that the statement is untrue that the sewage poured into the river at Windsor cannot be found seven miles below?—As a general proposition I should say it is untrue.

6374. Still I presume you are of opinion that water whilst it is flowing undergoes a self-purifying process when passing through the air from different parts of the surface becoming exposed to the atmosphere?—Yes, all the dead organic matter is constantly undergoing a slow process of oxidation; but as I have just now mentioned, in connexion with some experiments of my own on that subject, the process of oxidation is by no means so rapid as is generally supposed, because even after 190 hours, which I presume would be much longer than the time taken for sewage to flow even from Oxford to Teddington, the process of oxidation in the laboratory, with a temperature much higher than that which obtains in the Thames generally, because the temperature of the laboratory during this experiment was between 20 and 25 degrees centigrade, had proceeded to a very slight extent only.

6375. Then your general objection to the Thames water is on account of its sewage contamination, the result of human excreta?—That is the principal objection to be taken to it with regard to its effect upon health. Then as regards economy in washing and cleansing operations, there is its hardness also to be taken into account.

6376. Supposing the sewage were diverted from the Thames in pursuance of the existing law as carried out by the Thames Conservancy Board, would your objections be removed with regard to the Thames water being suitable for the supply of London?—They would be removed so far as the actual sewage was concerned. I should still object, although in a mitigated degree, to the drainage from cultivated land flowing into the Thames. But in speaking of the diversion of the sewage from such towns as Oxford and Windsor, the mere diversion of that sewage so as to throw it upon land, and then allow it to drain or to make its way into the Thames, would not overcome my objection to the water on the ground of the sewage, because I do not think that sewage which has been merely passed over land, or even through land, can be safely allowed to mix with water that is to be employed for domestic use.

6377. Then your gathering ground for the supply of large towns must necessarily be very limited if that view prevailed, that it should pass over no cultivated land, and that the smallest particle of sewage makes it unsuitable for domestic purposes?—If you have no choice of water, of course it would be much preferable to drink water that was contaminated only from the drainage from manured land, as compared with that which was contaminated directly by sewage. But sewage that has been allowed to flow over land, and which perhaps does not sink into the land at all, would, I should think, be much more objectionable than the water drainage from cultivated land, and which is manured principally from animal as distinguished from human manure.

6378. In the case of the 250 acres of land at Croydon upon which the sewage of that town is spread, the water running off into the Wandle is to the eye perfectly pure; have you ever examined any of that water to ascertain whether there is still held in solution that which is prejudicial to human health?—I have examined that particular water which you have mentioned, and also a number of other similar waters running off land upon which sewage has been placed. Those examinations have been recently made by Dr. Odling and Dr. Letheby and myself for the Board of Conservators of the Thames, and I may say that the substantial result, at least what I myself would say was the substantial result, of those examinations is, that about four-fifths of the sewage matter is destroyed under favourable circumstances, but that is all you can calculate upon. So that if you were to have all the sewage which is at present poured in an unmitigated form into the Thames distributed over the land as it is done at Croydon, you would reduce the amount of contamination of the Thames to one-fifth of what it is at present. In other words, if the population increased to five times its present amount, in the Thames basin the contamination would be as great as it is at the present day, after the sewage had passed over the land.

6379. Had the land taken up the ammonia?—The land had taken up a large amount of the ammonia, not the whole of it. It had taken out a great deal of the organic matter, amounting to four-fifths on the average, but had left the remaining fifth in, and I think that such water flowing, as we found it flowing in those cases, into the river Thames, would be an exceedingly objectionable thing to have in a river that was to be used for drinking purposes, but not at all objectionable as regards a river used for other purposes, or merely as an ornamental stream. I mean that it would be no nuisance to the inhabitants upon the banks.

6380. (*Mr. Harrison.*) With reference to the sewage contamination, I observe that in one of your weekly reports, taking first the one dated the 4th of May 1867, you refer to the water of the Chelsea Company as having an amount of sewage contamination equivalent to 2,195 lbs. of average filtered London sewage, and you add to that that "by gradual oxyda-"tion, partly in the pores of the soil, partly in the "Thames or its tributaries, and partly in the reser-"voirs, filters, and conduits of the company, this "sewage contamination has been entirely converted "into comparatively innocuous, inorganic compounds, "before its delivery to consumers," inasmuch as the expression "comparatively innocuous" is indefinite; what value are we really to attach to that term "comparatively innocuous?"—I may mention that my motive in using that word "comparatively" was to steer quite clear of a difference in opinion amongst medical men as regards the effect of nitrates upon the system. It is held by some medical men that they are peculiarly injurious, whilst others consider that they are innocuous. I confess myself that I do not think that they are at all injurious, but I wished merely to put the matter in that way, as showing that at all

events if they are at all noxious they are, compared with the original sewage, innocuous.

6381. Still we may take that as your own opinion; but going a degree further, supposing that the Thames water were properly filtered as you here suggest, partly in the reservoirs, filters, and conduits of the company, do you consider that that water (not taking exceptional cases) is innocuous so far as health goes?—I do not. I only consider that the products of the decomposition of this particular quantity of sewage which is present in the water as its skeleton, as I have called it, are innocuous; but the remaining unoxidysed portion of the sewage, if such should exist in the water, would of course not be innocuous. This statement leaves quite untouched the question whether there is undecomposed sewage in the water or not. As I have stated, I have only reported on that point on three occasions; and this statement is put in order that no one may imagine that all this quantity of previous sewage contamination means contamination which exists at the time that the water is taken for analysis. It is to prevent that impression that this explanation is given with regard to that particular part of the sewage.

6382. And with regard to that which you do say is injurious, you are hardly able to detect it?—Only rarely. Those waters are examined only on 12 days out of the 365, that is one point that must be taken into consideration. And I have only, in the case of the entire water supply, been able to get evidence which I consider anything like conclusive on this one occasion to which I have already alluded, namely, last month, on the 21st of January, when those waters contained this large proportion of organic nitrogen as compared with the organic carbon which they contained.

6383. That case to which you refer in January was quite exceptional, as I gather from your report of the 31st of January?—Yes; during the whole of the three years that I have examined these waters I have never found them in so bad a condition as upon that occasion, or in a condition approaching to that, but I may say that this condition of things having once set in, lasted the greater part of a month.

6384. In this report of the 31st of January you again repeat the words which I have just quoted; after giving the amount of sewage contamination in the water of the Chelsea Water Company you say: "By "gradual oxydation, partly in the pores of the soil, "partly in the Thames and its tributaries, and partly "in the reservoirs, filters, and conduits of the com- "pany, this sewage contamination had been converted "into comparatively innocuous organic compounds "before its delivery to consumers," and I think I find that almost word for word in all your weekly reports?—It is copied, in fact, from one to the other, it goes through the whole of them.

6385. Would that not rather lead the public to take it that your view was that this water was perfectly wholesome, or as nearly as possible perfectly wholesome?—I think it would, and that was the impression which I intended to convey, so long as I had not actually detected the presence of sewage matter unoxidysed in the water, at all events I was very anxious not to convey the impression that analysis had discovered anything actually injurious in the water.

6386. Do you agree with those remarks of your friend Dr. Odling, which are separate from your report, "Although London is at present provided with "an agreeable and in my opinion perfectly wholesome "water," &c.?—No. I do not consider it a perfectly wholesome water, I did not at the time this was written, and that, I believe, caused my colleague to give a separate postscript to this report.

6387. Have I hit upon the words of his report with which you rather disagree?—That was one of the principal points upon which we disagreed. At that time I could not go so far as to adopt that opinion of his, and now I could far less do so. Now I consider that the presence of unoxidysed sewage in the water is almost absolutely demonstrated.

6388. That is during this particular month of January?—Yes.

6389. In the month of January this year in your report you say: "The waters delivered in London "during the latter part of January by the Chelsea "and especially by the Southwark and Lambeth com- "panies, were in such a muddy condition as to render "them totally unfit for domestic use." On that point filtration properly carried out would have met, would it not, that part of your objection as to the water being muddy?—Yes, certainly.

6390. From that we may gather, may we not, that your view would be that the question of the proper filtration of the waters is one of vital importance?—I think it is a very important point.

6391. You also state in your annual report: "The "New River Company stands alone in the perfection "of its filtering apparatus. On no occasion during "the past year has this company's water exhibited "the slightest turbidity, thus proving that perfect "filtration is compatible with the largest daily supply "furnished by any one company in London." Do you see any reason why every company should not give out their water in the same perfect state that you here describe the New River Company does?—I see no reason whatever why the other companies should not.

6392. And do you consider that it would be a desirable thing in case of necessity that such a delivery of water in a pure state should be enforced by legislative enactment?—I do; in fact it is so enforced at the present moment.

6393. You also say: "The seven companies who "occasionally or habitually send out turbid water "subject the inhabitants of more than 300,000 houses "to the unnecessary expense of private filtration?"—Yes.

6394. Going back now to the words which you use in your report of January the 31st, that the waters of the other companies that you mention "were in such a "muddy condition as to render them totally unfit for "domestic use," you are clearly of opinion that that is an objection which might be met by adopting a proper method of filtration?—Yes, so far as muddiness is concerned it could be completely met.

6395. Then you describe the causes of this peculiar state of things in the month of January: "The "Thames has overflowed its banks above the point at "which the water supply is withdrawn, and by wash- "ing the surfaces of cultivated fields, and mingling "with the contents of stagnant ditches and ponds, has "become contaminated to an intolerable degree. Those "companies which, like the West Middlesex and "Grand Junction, possess ample and efficient filtering "apparatus, were enabled so far to cope with the "difficulty as to send out their supply free from sus- "pended matters. A week later, however, than the "date when the samples were collected the water of "the Grand Junction Company had also become "turbid, but much less so than that delivered by the "Southwark and Lambeth companies." This is the period during which you state that you found these waters to be in an unfit state?—It is.

6396. Assuming that the Act of Parliament which was passed last session for preventing the pollution of the river Thames is efficiently carried our, and that no sewage is directly discharged into the river, and assuming also that those companies adopt proper modes of filtration, would not this specially objectionable case be to a great extent met?—With regard to the muddiness of the water, it would completely, but not with regard to the wholesomeness completely. The unwholesomeness of the water would doubtless be mitigated by otherwise disposing of the sewage, or rather, I should say, by passing the sewage over the land before its admission into the Thames; but I do not think that even after that such a proportion of sewage would be innocuous when admitted into the Thames.

6397. I gather from your remarks that we are not for the future to take those words in your weekly reports in the popular sense in which one would ordinarily read them, as to the comparatively innocuous qualities of the water?—That is my own individual opinion, that the nitrates, nitrites, and ammonia are perfectly innocuous.

Dr. E. Frankland, F.R.S.

27 Feb. 1868.

6398. Looking to future reports, and considering the views which you now entertain, we should probably not see the same words in that same form in future reports?—I think that those words will substantially be in the same form, but I shall probably now proceed to report upon the unoxydised sewage. These words refer only to the oxydised and decomposed sewage. I have hitherto refrained entirely, except in the three cases which I have mentioned, from saying a word about the unoxydised sewage, because it was present in such small quantities that I did not consider that the indications which I had of it were outside the errors of experiment. But now, during the next few months or during the present year, if I find further evidence of this actual sewage contamination, as I term it, in contradistinction to previous sewage contamination, some remarks upon that point will no doubt appear in those reports.

6399. Is it not quite possible that with an exceedingly large amount of previous sewage contamination the water may still be perfectly harmless?—It is possible, that is to say, on certain assumptions.

6400. May we not assume that, however contaminated the water may have been upon your principle of previous contamination, still you may find it on analysis to be perfectly pure and wholesome?—Yes; for if the water had been boiled for an hour or two it would still exhibit the same thing as previous sewage contamination.

6401. Or by a large extent of filtration through a very extensive porous soil?—Yes, but I should not be prepared to say that after any amount of filtration we should be guaranteed from the presence of those minute germs, which being smaller in some cases, as they have been proved to be, than blood globules, would pass through the pores of the chalk, for instance, like human beings pass through the streets of London.

6402. Still you are not able to detect those globules?—No, they are beyond the reach of the chemist, and so far of the microscopist, I believe.

6403. They must have existed in the sewage in some form or other previously, must they not?—It is not certain that they exist in all sewage; in fact, we may say that the particular germs which are believed to give rise to such diseases as typhus fever and cholera have never been actually identified in water at all, or in sewage even.

6404. Might not we, perhaps, take it that your view is rather a negative than a positive one as to the danger from using that water, rather in this sense, that it is not positively a dangerous water, but that it may contain the germs of danger in it?—Yes; I would not say that that particular water on the table, which is the worst sample, perhaps, certainly the worst sample I have met with, could not be drunk with impunity; we have no evidence to show that it could not be so drunk with impunity; but if that water were in that condition during a period of epidemic cholera, and the discharges of cholera patients had got into it, it would be exceedingly probable, although even then it would not be absolutely certain, that that water could not be drunk with impunity.

6405. Will you be good enough to give us a reference to those three cases which you have mentioned; are they referred to in the Registrar General's weekly reports?—Yes, they are all in the weekly reports. I am afraid I have not the weekly report which contains the exact words used in my report upon those cases, but this is as nearly as possible a copy of them as contained in a published lecture of mine upon the subject, delivered at the Royal Institution not quite a year ago: "By operating upon one litre of water "for the determination of total combined nitrogen, "one per cent. of sewage can be detected with certainty; but smaller per-centages ought, in operations upon such a small quantity of water, to be "considered as falling within the possible errors of "experiment. Thus, in the table of analytical results "given below, the indications of organic nitrogen, "and consequently of present sewage contamination, "amounting in the maximum to one-half per cent., "ought to be disregarded; because as the total combined nitrogen was determined in one litre of each "water, the amount of present sewage contamination "indicated by the analysis falls within the limit of "possible experimental error. The subjoined tabulated results obtained in the analysis of samples of "the metropolitan waters collected in February last "and during the present month, show therefore that "none of these waters contained as much as one per "cent. of present sewage contamination. This "search for unoxydised sewage or its equivalent in "a water may be rendered more minute by operating "upon a larger volume of water, by which the possible error of experiment is reduced in proportional "amount; thus, if 10 litres of water be used for the "determination of total combined nitrogen, one-tenth "per cent. of present sewage contamination can be "ascertained with certainty. This operation has "been performed upon 10 litres of the Thames water "delivered by the Grand Junction Company, and "collected during the present month" (that is, March 1867), "and it is satisfactory to find that this minute "examination failed to detect any actual sewage contamination, consequently the sample of the Grand "Junction Company's water operated upon did not contain one-thousandth part of its volume of unoxydised "sewage." That was one case. The other case was a similar one, in which the East London Company's water from the Old Ford reservoir was submitted to this detailed analysis; 10 litres of it were taken, and that analysis also failed to demonstrate the presence of unoxydised sewage in that water. The other case was that of the West Middlesex Company's water collected on the 1st of June at the cab rank in Portland Road, about which the following remarks are made in the monthly report dated Saturday, June the 29th, 1867: "The "above analytical results show that the water of the "West Middlesex Company, drawn from the standpipe at the cab rank in Portland Road, on the 1st "instant, was contaminated with sewage" (present sewage contamination), "for, if the amount of nitrogen "existing as nitrates, nitrites, and ammonia (·318 "part) be deducted from the total combined nitrogen, "there remains ·103 part, which must be organic "nitrogen, equivalent to 1,030 parts of average "London sewage in 100,000 parts of the water, "or rather more than 1 per cent. The water was "turbid when drawn, and after standing for a few "days emitted a very offensive odour, and became "filled with white floculent matter, resembling that "which gradually deposits from filtered sewage. A "few days later this odour disappeared. In answer "to my inquiries the engineer of the company informs "me that a breakage had occurred in one of the "company's mains in an adjoining street, and near a "gully hole. This fracture, which was repaired on "the 3d of June, soon after its discovery, happened "to a main from which the water pressure was "removed at night, and it is believed that during "this absence of pressure sewage commingled with "the contents of the main. It is gratifying to find "this satisfactory reason for believing that this contaminated water was delivered to a small district "only, and for a short time, but this accident supplies "another item to the already long list of dangers "attending an intermittent supply of water."

6406. That would have been equally the case if you had been getting water from Wales, would it not?—Yes, on the intermittent system in that particular case.

6407. And in the case which you referred to before, they were both exceptional cases?—In the other two cases no sewage was discovered.

6408. Have you discovered this unoxydised sewage in any case in the ordinary water as supplied, where there has been no accident at all?—If you call it an accident on the 21st of January, I have not. I have not discovered it under ordinary circumstances except upon this one occasion, but there it was discovered in the water delivered by three different companies on the same day.

6409. Under the circumstances which you have described in your report which I have read of a particular flood in the Thames at the time?—Yes.

6410. I presume you know Dr. Letheby's opinion upon this question?—Yes, I do.

6411. And that he does not agree with you?—No, I do not think he does. As to the danger of contamination by sewage, in some respects he agrees with me. When we talk of well waters we are perfectly agreed about them, but with regard to river water we differ.

6412. In fact, his views would be perfectly expressed by reading what you state in your report, if I may put it in these words: "By gradual oxidation, "partly in the pores of the soil, partly in the Thames "or its tributaries, and partly in the reservoirs, filters, "and conduits of the company, this sewage contami- "nation had been entirely converted into," instead of "comparatively," "a perfectly innocuous inorganic "compound?"—Yes.

6413. If I put the word "perfectly" for "comparatively" in your case, that would express his opinion entirely upon this question?—I should have no difficulty in changing that word from "comparatively" to "perfectly," as expressing my own opinion upon the subject, certainly; but I think I have heard Dr. Letheby say that those nitrates are not perfectly innocuous when they are present in large quantities.

6414. I am taking that as his opinion as applied generally to the water of the Thames?—Yes, that small quantity he would also pronounce to be perfectly innocuous; but large quantities of nitrates are believed by many medical men to exert a deleterious effect.

6415. You do not arrive at the conclusion that the Thames water is so injurious to health that at any cost it ought not to be used?—I think if any other source were obtainable, even at a great additional cost, it ought to be preferred to the Thames water.

6416. Of course, in all this I am going upon the assumption that the Act of last session is fully carried out, which prevents the discharge of all sewage into the Thames?—If you are proceeding on the assumption that the sewage will not in any manner make its way into the Thames, that is impracticable, I believe.

6417. No, the sewage would be placed over the land and would still find its way by filtration through the soil into the Thames, and in many cases into the chalk, and that might not come into the Thames?—I should think that even under those modified circumstances the water would still be unfit for domestic use.

6418. (*Sir B. Phillips.*) You have spoken of the system of filtration adopted by the New River Company, and you say that that company stands alone in the perfection of its filtering apparatus. Supposing all the other companies were to adopt the same process of filtration as the New River Company appears by your report to have adopted, would that remove your objection?—Not entirely; it would mitigate it, but not entirely remove it, because we have no proof whatever that filtration even of the best kind can remove certain objectionable matters which are present in sewage. We know that the white rice-water evacuations of cholera patients cannot be so removed.

6419. But we are to understand you to say that it would partially remove your objection?—Yes, certainly it would; I would much rather have well-filtered water than water that is not filtered.

6420. (*Sir J. Thwaites.*) Are not all the companies under obligation to filter since the passing of this Act of 1852?—Yes, they are all supposed to filter perfectly at the present time.

6421. (*Col. Harness.*) You have alluded to some experiments which you made with choleraic matter mixed with a proportion of pure water. Supposing that mixture had been sent to you as a sample of water without your knowing how it was composed, how would you have reported upon it?—I should in all probability have reported, in fact I should certainly have reported at that time that that water was slightly turbid, but in other respects an exceedingly pure water; and even now I do not know that I could report differently upon it, because it was mixed with distilled water, and the proportion of organic matter put into the distilled water by that mixture of $\frac{1}{1000}$th part of this evacuation was so small that it would have been much less than that which was found in Thames water, and much less than that which is found in the water in Cumberland and Wales.

6422. Would you have reported that water as better than the water that is now drank in London?—Most certainly I should, with the exception of turbidity. I think that turbid water on account of its constant danger of contamination is always to be rejected.

6423. (*Mr. Prestwich.*) Might not the superiority of the New River water at the date you mention arise as much from the different source of supply as from the superior methods of filtration?—My remark is founded upon an examination of those waters during an entire year, and during the whole of the year 1867 the New River Company's water was never on any single occasion in the slightest degree turbid, but that was the case with no other water delivered in London.

6424. Would not you rather ascribe that to the circumstance that the New River water is derived principally or to a large extent from chalk springs, and does not flow over any extent of meadow land, whereas the Thames water is derived in some part from water flowing off clay land, and is subject to floodings of the marsh lands in its course?—No doubt in regard to the samples collected last January I should say so, but I have seen the New River water entering the New River head at the River Lea turbid, and requiring good filtration to render it bright, and yet, seeing that water entering their works at that point in that condition, I find that when it is delivered to the consumers in London it is perfectly transparent, and therefore I conclude that they have very efficient means of filtration.

6425. But is not a large portion of the New River water derived directly from chalk springs and wells?—I am not able to speak of the proportion of the two sources, but I know that they have several wells from which they pump a considerable quantity of water, but whether that constitutes a very large proportion of the total supply I am not prepared to say.

6426. What should you consider the essential conditions of a good drinking water?—The essential conditions of a good drinking water I should take to be, first, coolness and aëration; secondly, freedom from animal organic matter of all kinds; thirdly, that it should never have been contaminated by sewage or manure in any form; and, fourthly, that it should be soft water, not over five degrees of hardness.

6427. But have you not expressed an opinion before, that the question of hardness or softness was not important as regards a drinking water?—I beg your pardon. I thought your question referred rather to the general question. As regards a drinking water only, I should not object to a considerably greater amount of hardness than I have mentioned—it might be as hard as Thames water as a drinking water, or even harder for anything that I know, I do not know that there is any reliable evidence as to injury having resulted from drinking hard water.

6428. Should you not consider some of the chalk springs in the neighbourhood of London, or springs coming from the greensand, as furnishing water of unexceptionable quality as drinking water?—If it were not for the uncertainty regarding the possibility of filtering this noxious matter out of water, even by its passage through several hundred feet of chalk or greensand, I should undoubtedly think such water to be good water.

6429. (*Mr. Harrison.*) Is it not the fact that upon the average of the whole of last year the New River water contained a larger proportion of previous sewage

Dr. E. Frankland, F.R.S.

27 Feb. 1868.

contamination than all the rest, with one exception, taking the mean of the whole?—Yes, with one exception, namely, the Kent water; and probably the exception throws light also upon the cause of the source of contamination of the New River water, because they pump out of the chalk to some extent, as Mr. Prestwich has just mentioned. With regard to this previous sewage contamination, I ought perhaps to mention that I do not consider that this contamination is of the same value, so to speak, or ought to be looked upon in the same light in all waters. Previous sewage contamination in a water which has been but very slightly filtered is a very much graver charge to be brought against it than previous sewage contamination in a water that has been filtered through a very thick stratum like that of chalk. In fact, I have already said that I would rather drink water that was four times as much contaminated previously by sewage or manure matter, if it had filtered through a hundred feet of chalk, than I would drink water containing a smaller proportion of previous sewage contamination which had merely flowed down a river.

6430. Taking it in the form in which it appears in this table in your report, the amount of previous sewage contamination really cannot have any substantial value attaching to it to determine what is the state of the water, because you take it from all the supplies in the same condition, and then you take it from the mains as it is delivered?—This table of previous sewage contamination shows only the amount of animal organic matter with which the water has been in contact expressed in terms of average filtered London sewage.

6431. But it does not give any information as to its present condition?—Yes, also as to its present condition, which is perfectly innocuous so far as that amount of sewage is concerned.

6432. (*Mr. Prestwich.*) As regards that point of previous sewage contamination, you have just stated that you attribute this previous sewage contamination entirely to decomposing animal matter; but from your answers to the questions which I put to you before may I not fairly arrive at the conclusion that the case is altogether hypothetical?—I think what I said was this, that no doubt vegetable matter could possibly give rise to the production of nitrates and nitrites in its decay, but I believed that it was not the case to any appreciable extent in the conditions affecting water in this country, inasmuch as I find no traces or very slight traces of those compounds in water from localities where it has been contaminated only by vegetable matter.

The witness withdrew.

Professor W. Odling.

Professor WILLIAM ODLING examined.

6433. (*Sir J. Thwaites.*) You are a Bachelor of Medicine and a Fellow of the Royal Society, are you not?—Yes.

6434. And I believe you are Professor of Chemistry at St. Bartholomew's?—Yes.

6435. In conjunction with Dr. Frankland you have made analyses, have you not, of several waters collected by Mr. Pole?—Yes.

6436. Having heard the evidence of Dr. Frankland, do you generally concur in his evidence, as we may gather from your report, with regard to the analyses of the waters from the Welsh and the Cumberland districts?—Yes, quite so.

6437. Do you concur with Dr. Frankland's view of the advantage of soft water for domestic purposes as well as for manufacturing purposes?—I think that, excepting for drinking purposes, soft water is upon the whole preferable to a hard or even to a moderately hard water like the Thames.

6438. For manufacturing purposes would not soft water have great advantages over hard?—Yes, except in very special cases.

6439. On the score of health do you make any distinction between soft and hard water?—I do not think there are any facts which enable one to give a positive opinion. Some gentlemen who have considered the subject entertain very strong opinions both ways; but I do not know any facts upon which one can speak positively.

6440. You have carefully examined the waters from the sources of the Severn and the waters taken from the Lake districts, and compared those waters with the water supplied by the several companies in the metropolis, what is your opinion as to the relative values of those waters?—I would say that the waters proposed to be taken from Wales and Cumberland are sufficiently alike to be considered as one, and the waters supplied to London from the Thames and the Lea are sufficiently alike to be considered as one; and I would say that although the waters of Wales and Cumberland are in some points inferior to those by which London is now supplied, still upon the whole they are superior, more especially in consideration of their softness.

6441. Are we to understand you to say that the waters of the Lake district and the Welsh district are in some respects inferior to the water supplied to London?—Quite so, but taking them altogether they are superior.

6442. Will you be good enough to explain the inferiority?—They are less bright, they are not so colourless, and they are not so well aerated. Of course I am speaking comparatively only. They are not waters of bad colour, or bad appearance, or bad aeration, but Thames water is better in these three points.

6443. But are you of opinion that, supposing the Act of last year were faithfully carried out, and the sewage were intercepted from the river Thames, the water on the whole would be a suitable water for the supply of London for domestic purposes?—Yes, I am.

6444. Are you of opinion that the advantages of the soft water from the Lake district and the Welsh district would be worth the additional expenditure which would be involved in bringing them to the metropolis for the supply of the inhabitants?—That I can hardly say, because I have no knowledge whatever about the expenditure.

6445. But having a choice between the two waters, to which would you give the preference having regard to all considerations?—If they were both at my door, or within a mile or two, I would certainly take the Welsh or the Cumberland water in preference to the London water.

6446. But that preference is not so strong as to lead you to recommend a heavy expenditure for the selection of one as compared with the other?—It is not.

6447. You have examined the Thames water from time to time, have you not?—I have examined it fully.

6448. Have you found in those examinations of the Thames water the presence of sewage not decomposed?—I have not.

6449. Do you attach the same importance to the presence of sewage as affecting human health as that which Dr. Frankland has given utterance to?—On general grounds, I think, it would be very objectionable to drink water that was known to be contaminated with any appreciable proportion of sewage, as sewage.

6450. Have you examined the water at the point where sewage has been discharged into the river, and have you examined the same water at a distance of three or four or five miles lower down, and if so what has been the result?—I seem to have an impression of having made such experiments on some particular occasions, but I cannot call the details to mind.

6451. Has your attention been directed to the important principle of the self-purifying process which is going on in rivers running at a given velocity?—Yes, it has. There may be great differences of opinion as to the degree to which that self-purification takes place, but that it does take place to a very considerable extent I think is undeniable.

6452. You will understand my question as not referring to sluggish waters, but to rivers where the body of water would become exposed to the action of the atmosphere as it passes along?—You may see in many rivers, even sluggish rivers, having sewage discharged into them, that for a mile or two the appearance of the river is affected by the sewage, but beyond a certain distance there is no recognizable effect at all, the weeds are perfectly clean and perfectly healthy.

6453. Do you know Leicester at all?—Yes.

6454. Do you know the condition of the river there?—Yes, I do.

6455. Near to the town it was in a very bad condition, and the water quite black, was it not, when you saw it, from the refuse of manufactories and the discharge of sewage?—Yes.

6456. Did you observe the condition of that river three miles from the town?—Yes, and from its appearance you could not tell that it had been contaminated, it was running clear, with fish swimming in it, and the weeds were clean.

6457. And that simply from the process of self-purification?—Quite so.

6458. Have you ever examined the water of that river so as to detect the presence of sewage, although it appeared clear?—No, I have not.

6459. You have not detected any of the skeleton forms which Dr. Frankland has given utterance to?—That is a point on which I am a little at issue with Dr. Frankland, with regard to the interpretation to be put upon the presence of nitrates in water. It is admitted that the presence of nitrates says nothing for the present condition of water at all, and I rather dispute that it says anything very important for its history. There is no doubt that a very large quantity of sewage, or the equivalent of sewage, is discharged into the river Thames above the source of the present water supply, and I do not mean to say that Dr. Frankland exaggerates that proportion at all—I do not know whether he does or does not—but I contend that the estimation of the nitrates in a water does not give any ground on which to estimate its proportion of sewage.

6460. But when found are they in your judgment injurious to the water?—In such quantities as are found in the river supply of London they are, in my opinion, perfectly innocuous.

6461. Still less, I suppose, if found in chalk?—Yes, quite innocuous if found in chalk.

6462. Is it your opinion that those which have been found in chalk are due to sewage?—It is a point upon which there is no positive evidence, but I am inclined to think that it is not so, for we find them distributed so irregularly. For instance, the deep-well water at Trafalgar Square, and the deep-well water from the greensand, and lower chalk all over London, is nearly free from nitrates and nitrites; whereas the water of equally deep wells elsewhere in the chalk is found to contain very considerable quantities of nitrates. The deep well-water from nearly all formations has been found to contain nitrates. Then, moreover, a proportion of the nitrates which the sewage itself undoubtedly does furnish, in one case is destroyed and in another case is not; and so far as the history of the water is concerned, in the one case where the nitrates are destroyed, that water may show but a very small amount of previous sewage contamination, whereas it might have had a much larger amount than the other.

6463. Apart from the question of sewage, is it your opinion that the condition of the Thames basin is such as to render it an unfit gathering ground of water for domestic purposes?—I do not think it at all unfit.

6464. (*Sir B. Phillips.*) You state, do you not, that supposing the two supplies, the Thames and the Lea and the Lakes, were within equal distance, you would prefer the Lakes' supply to the other?—Yes, I should.

6465. Supposing that you were a London ratepayer living in an expensive district, paying say a rate of 6*d.* for the Thames water, do you think that you would feel disposed to have your rate doubled for the purpose of obtaining the Lake water?—Unless I were a manufacturer I certainly should not.

6466. As a manufacturer it would become a question of trade, of course; but supposing as a private gentleman with a family living in one of the expensive districts of London, with a house heavily rated, you had the choice of the London water at a rate of 6*d.*, and of the Lake water at a rate of 1*s.*, do you think you would pay the double rate for the purpose of having the Lake water?—I do not think I should.

6467. Then do you agree with Dr. Frankland, that supposing a system of perfect filtration were adopted (and he appears to consider that the New River Company has a perfect system of filtration), and if all the companies were to use the same process, we should have a water perfectly wholesome for domestic purposes?—Certainly I do.

6468. (*Mr. Prestwich.*) You heard the questions which were put to Dr. Frankland with regard to the quality of these waters. As to their freedom from mineral impurity there can be no doubt. Do you agree with him in his views with regard to the presence of organic nitrogen and organic carbon?—Yes.

6469. These analyses show, do they not, that in those respects the Welsh and Cumberland waters possess no superiority over the London water?—Precisely so.

6470. Do you consider that the presence or absence of these substances forms an essential consideration in estimating the quality of a water?—If a water contained a large proportion of organic nitrogen I should say it was bad.

6471. Do not you consider that the quality of water for drinking depends mainly upon the presence of organic nitrogen in it?—Yes, substantially that is so.

6472. And that the presence of nitrates, if not in excess, is a comparatively unimportant element?—It is an unimportant element as to its state, and I believe it to be in many cases an unimportant element as to its history.

6473. You have heard the questions that were put to Dr. Frankland with regard to the probable origin of nitrates. Are you of opinion that their origin may be traced to several sources?—I am quite of that opinion.

6474. With regard to the presence of nitrates in the deep chalk wells of the Kent Company that have been referred to, they show a quantity of nitrates present as large or larger as in the Thames water; but it does not follow, does it, that they are necessarily derived from the same source?—Certainly not.

6475. Is it not unlikely that at the Grenelle well, where the water rises from a depth of 1,800 feet, and the source of which is 120 miles from Paris, that the nitrates in such water should have such an origin?—I was not aware of that, but I daresay it is so.

6476. Do not you consider that it is improbable that such nitrates in water passing 120 miles underground should be derived from sewage contamination?—Yes; the quantity of nitrates found in this water and in many other deep-well waters from the new red

Professor W. Odling.

27 Feb. 1868.

sandstone, the old red sandstone, and the greensand, negatives the idea of their being always derived from sewage contamination.

6477. What do you consider to be an essential quality of good water for drinking purposes? — It should be bright, colourless, and brisk, and it should not contain any considerable amount of nitrogenous organic matter.

6478. What is your opinion with regard to the presence of carbonate of lime?—For mere drinking purposes I do not consider it a matter of any disadvantage at all.

6479. Do you think that there is no risk in using for drinking purposes waters which are derived from rivers the population on the banks of which is constantly increasing?—Of course it is conceivable that the amount of impurity discharged into a river may exceed the power of the river to purify itself, or approximate so nearly to that power as to leave a balance that it would not be safe to rely upon.

6480. Has it not been found that even with the best filtering apparatus, after a time the filter becomes clogged, and the water which passes through is apt still to retain its organic impurities?—I should think that so far as mere filtration was concerned, by a sufficiently frequent cleansing of the filter there would be no danger from inadequate filtration, even if the water were very bad indeed; but I think that the soluble matter of the sewage might in some cases become so large from the proportion of sewage discharged into the river, that the water would be quite unfit for drinking purposes, even although it was filtered perfectly.

6481. (*Mr. Harrison.*) But that would not be the case with the Thames?—No.

6482. (*Mr. Prestwich.*) The subject of the analysis of water with a view to detect organic matter is one of extreme difficulty, is it not?—Yes, of extreme difficulty, and we are all much indebted to Dr. Frankland for the great improvements that he has introduced into the mode of determining the organic matter of water.

6483. Do you think that it is capable of still further improvement?—Yes, I think it is.

6484. Do you consider that the process which has been lately introduced by Mr. Wanklyn will prove useful with further improvement?—The process which Messrs. Wanklyn and Chapman have introduced is at present in rather an immature state, but I think it very likely that with more work bestowed upon it, it may prove a useful comparative process.

The witness withdrew.

Adjourned to Wednesday next, at 12 o'clock.

Wednesday, 4th March 1868.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND, K.G., IN THE CHAIR.

Sir JOHN THWAITES.
Alderman Sir BENJAMIN PHILLIPS.
Colonel HARNESS.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

J. F. Bateman, Esq.

4 March 1868.

JOHN FREDERIC BATEMAN, Esq., further examined.

6485. (*Chairman.*) When you were examined last year you promised, did you not, to produce some plans and documents for the Commission?—I did, and I shall now be happy to hand them in. The first table gives the returns of rainfall in different localities indicating the effect of mountain ranges. I tried when I first had the honour of addressing the Commission to explain the reasons why I had come to certain conclusions with regard to the fall of rain in the particular locality which I had taken for the supply of water, from the actual known fall in situations which were, as far as could be, analogous to the situation which I had chosen. I daresay it will be remembered that I pointed out various localities, in Scotland for instance, across ranges of hills, to show how the rain was greater on the westerly side than on the easterly side of a mass of mountains, and how it greatly increased in the first trough of hills and decreased in succeeding ridges and succeeding troughs. I will not, if I can help it, repeat any of the evidence which I had the honour of giving before, but I will hand in now the tables which you were then kind enough to ask for, which show the state of things which I was anxious to describe.

The first table shows the rainfall along a line commencing at Standish, near Wigan, in Lancashire, crossing the watersheds of the Liverpool and Bolton waterworks and terminating at the Blackburn waterworks, the direction being from south-west to north-east.

TABLE No. 1.

Showing the RAINFALL along a Line commencing at Standish, near Wigan, crossing the Watersheds of the Liverpool and Bolton Waterworks, and terminating at the Blackburn Waterworks; the direction being from S.W. to N.E.

Years.	Wigan Waterworks, Standish. Elevation 300 ft. above O.D.	Liverpool Waterworks, Rivington. Elevation 700 ft. above O.D.	Bolton Waterworks, Belmont. Elevation 800 ft. above O.D.	Blackburn Waterworks, Pickup Bank. Elevation 650 ft. above O.D.
	Ins.	Ins.	Ins.	Ins.
1856	—	49·60	52·5	40·1
1857	—	41·16	43·4	42·5
1858	36·10	43·60	43·7	38·7
1859	37·35	46·84	53·4	44·3
1860	46·04	51·31	59·8	55·0
1861	47·63	46·38	55·7	48·7
1862	49·01	48·51	61·9	53·8
1863	44·70	51·01	66·0	48·0
1864	34·79	39·03	48·2	34·1
1865	33·48	34·80	42·6	35·6
	This gauge is in the open country.	The above is the result of several gauges placed at different heights on the westerly side of the hills.	This gauge is in the first deep valley to the east of the first range of hills.	This gauge is in a valley further to the east, with intervening hills.

You will observe, with reference to the first column of this table, which includes the rainfall from 1858 to 1865, by a foot-note at the bottom of the column,

that this gauge is in the open country, near Wigan, Wigan being in a comparatively open country away from the hills. I have not calculated the mean rainfall, but you will be able to see it in any one year. If you take the first year, 1858, you will find the rainfall 36·10 inches. The next column is the mean of seven gauges, spread over the watershed of the Liverpool waterworks, which are placed at various elevations, but having a mean elevation of 700 feet, which is the mean elevation of that watershed; and those gauges are all on the westerly slope of the first range of hills, against which the rain clouds, coming from the Irish sea, will impinge. If you take the same year to which I have referred, 1858, you will find the rainfall 43·6, showing how the rainfall increases by the rain clouds impinging upon the western slopes of that range of mountains. The next gauge is at the Belmont reservoir of the Bolton waterworks, which is just over the summit of the first range of hills and in the first deep trough, and the rain there in the particular year which I happen to have selected, 1858, is 43·7, as nearly as possible the same as on the Liverpool drainage ground; but if you look at the next year, 1859, (and almost any other year tells the same story,) you will find that the rain in 1859 was 46·84 on the average, on the Liverpool drainage ground, and 53·4 at the Bolton waterworks. The next gauge is further to the east, and is not quite the next trough, but there are comparatively no summits intervening between it and the trough of the hills in which the Bolton waterworks are situated, and it shows for 1859 44·3. That shows the manner in which the rain gradually increases under certain physicial conditions, and how it decreases the further you go in an easterly direction.

The next table shows the rainfall along the line of the Rochdale canal across the Penine chain of hills from Rochdale, at the foot of the western slope to Sowerby Bridge at the foot of the eastern slope of hills.

Table No. 2.

Showing the Rainfall along the Line of the Rochdale Canal from Rochdale to Sowerby Bridge. Direction from S.W. to N.E.

Years.	Rochdale.	WhiteHolme, Blackstone Edge.	Toll Bar, Blackstone Edge.	Black House, Blackstone Edge.	Sowerby Bridge.
		Elevation 1,200 ft. above O.D.	Elevation 1,000 ft. above O.D.	Elevation 1,000 ft. above O.D.	Elevation 300 ft. above O.D.
	Ins.	Ins.	Ins.	Ins.	Ins.
1846	31·7	43·2	43·9	42·5	27·90
1847	31·3	47·8	48·1	46·3	29·38
1848	39·7	66·7	67·5	66·6	32·27
	At foot of hills, westerly side.	Near summit of hills.			At foot of hills, easterly side.

I need not go over the whole of those columns, but I would merely mention, alluding to the foot-note at the bottom of the first column, that the Rochdale gauge is at the foot of the hills on the westerly side. The three next gauges are near the summit of the hills, and they all show a very considerable additional quantity of rain to that which occurred at the foot, and they are pretty nearly all on the same level. The next gauge, at Sowerby Bridge, which is at the foot of the hills on the easterly side, and where the rainfall is less than at the westerly foot, speaks for itself.

The next return which I have to hand in shows the rainfall along the line of the Manchester, Sheffield, and Lincolnshire railway, through the Longdendale Valley, in which the Manchester waterworks are constructed, almost direct west and east, and in the valley of the Don down to Sheffield. It shows the manner in which the rain increases towards the head of all valleys which are land-locked by hills of considerable elevation.

Table No. 3.

Showing the Rainfall along the Line of the Manchester Sheffield and Lincolnshire Railway, from Manchester along the Longdendale Valley, in which the Manchester Waterworks are constructed, to Sheffield. Direction from W. to E.

Years.	Manchester. Elevation above O.D. 194 ft.	Manchester Corporation Waterworks. Rhodes Wood Reservoir. Elevation above O.D. 500 ft.	Manchester Corporation Waterworks. Woodhead Reservoir. Elevation above O.D. 800 ft.	Stations of the Manchester, Sheffield, and Lincolnshire Railway. Woodhead. Elevation above O.D. 939 ft.	Dunford Bridge. Elevation above O.D. 954 ft.	Penistone. Elevation above O.D. 717 ft.	Sheffield. Elevation above O.D. 288 ft.
	Ins.	Ins.	Ins.	Ins.	Ins	Ins.	Ins.
1859	38·63	46·34	53·35	57·64	58·56	39·66	25·11
1860	41·40	47·85	53·69	66·35	62·79	30·11	27·58
1861	34·43	40·22	44·24	49·64	47·88	27·02	25·55
1862	43·95	47·28	49·63	48·51	52·55	29·09	28·93
1863	44·71	48·04	53·77	55·07	59·46	32·26	30·87
1864	34·33	38·50	43·52	39·98	39·21	24·80	22·56
1865	27·27	37·25	40·35	36·79	41·44	26·73	26·81
1866	43·64	58·45	64·58	66·39	67·15	41·85	33·12
1867	31·47	49·55	55·96	52·83	55·94	28·46	29·96
	In the plain.	In the valley of Longdendale.			In the valley of the river Don.		

If you take the first year, 1859, from that table, it appears that the rain at Manchester was 38 inches in round numbers; at the Rhodes Wood reservoir, which is the lowest of the reservoirs, it was 46 inches; at the Woodhead reservoir, which is a reservoir second above that, 53·35 inches, and at Woodhead, which is a little higher than the reservoir at the upper end of the valley, it was 57·64 inches. From that point the hills rise abruptly, and then just over the hills, at Dunford Bridge, which is to the east, it was 58·56, being a trifle more than it was at the westerly side; at Penistone which is a very short distance off, it sank to 39·66, and at Sheffield it was down to 25·11 inches. That shows how much the conditions of the country and the physical features have to be taken into account when determining from known results in other places the probable amount of rain in places where you have not the advantage of rain gauges.

The next return shows the rainfall on the ridges between Loch Lomond and Loch Lubnaig.

Table No. 4.

Showing the Rainfall on the Ridges between Loch Lomond and Loch Lubnaig. Direction W.S.W. to E.N.E.

Years.	On easterly flanks of Ben Lomond. Elevation above O.D. 1,800 feet.	On Ridge between Loch Ard and Loch Katrine. Elevation above O.D. 1,500 feet.	On westerly flanks of Ben Ledi. Elevation above O.D. 1,500 feet.
	Inches.	Inches.	Inches.
1854	109·0	67·1	61·9
1855	69·9	No return.	56·1
1856	81·0	74·1	No return.
1857	85·5	74·2	48·3
1858	90·4	97·1	55·2
1859	91·8	85·3	48·0
1860	83·5	73·5	53·8
1861	99·9	103·1	70·4
1862	114·7	102·7	66·0
1863	117·0	95·2	70·7
1864	68·0	76·1	69·0
1865	67·2	81·2	57·7
1866	100·1	89·8	Incomplete.
1867	Incomplete.	Incomplete.	53·0

J. F. Bateman, Esq.

4 March 1868.

I have not with me a complete map of that part of the district, but I daresay this will be sufficient (*producing a map, and explaining the situation of the lochs and mountains upon it*). There is a second range of hills and a third range of hills beside the hills which lie away in Argyleshire. On the easterly flanks of Ben Lomond, taking the first year, at the point marked on the map at an elevation of about 1,800 feet, the rainfall is 109 inches in 1854; on the next ridge of hills between Loch Ard and Loch Katrine, and at an elevation of 1,500 feet, it is 67 inches; and on the next ridge of hills, the westerly flanks of Ben Ledi, the valley of Loch Katrine, and Loch Vennachar being between, it is 62 inches in round numbers. The rainfall at the head of Loch Katrine, at Glengyle, is as great as it is upon the flanks of Ben Lomond, above 100 inches in the year. Those are the returns which I promised the Commission with respect to that portion of my former evidence.

The next document which I hand in, according to promise, is a plan and section of the Loch Katrine aqueduct. The aqueduct commences at Loch Katrine, about one-third of the distance down, or about $2\frac{1}{2}$ miles from the upper end of the Loch; and it passes along in the direction indicated on the plan, crossing several great hills and valleys, and terminating, as far as the built aqueduct is concerned, at a place called Milngavie, which is in the valley of the Clyde, and from there it is carried by pipes to Glasgow.

6486. What is the distance?—About 27 miles to the Mugdock service reservoir, near Milngavie, and 35 miles altogether to Glasgow. The details show the various modes of construction of the aqueducts and tunnels, and will give a tolerably complete representation of the mode in which the Loch Katrine aqueduct is constructed, together with a plan and section (*delivering in the same*). In our first tunnel, which was under a hill, the summit of which at the point where we cross it is about 600 feet above the tunnel, we had 11 different shafts, four of which were between 450 and 500 feet deep, within about 110 or 120 yards of each other; it is in hard rock, mica slate very much twisted. We were about three years or rather more in driving that tunnel.

6487. (*Sir J. Thwaites.*) How long would it have taken you to have finished that tunnel without the assistance of those shafts which give you additional faces?—I should think 10 or 12 years; along Loch Chon we considered it very good work if we made four yards in a month, working night and day at one face. The Loch Katrine tunnel was not quite so hard a material as the material alongside Loch Chon.

6488. (*Chairman.*) What is the next point in which you have additional evidence to furnish to the Commission?—I was next requested to show the gathering grounds appropriated to the supply of water in Lancashire and Cheshire. I am sorry that I cannot hand it in to the Commission in quite so complete a condition as I would wish; but I have prepared a plan which begins as high as Lancaster (*delivering in the same*). The population of Lancaster is 14,457 according to the census of 1861. The extent of ground over which they have more or less a certain amount of right to take water is indicated by the blue line. That includes the land which is drained down to the compensation reservoir which they have to make, but the land which is specially appropriated to Lancaster is shown by the two patches of blue. The drainage ground of Fleetwood, Blackpool, Kirkham, Poulton, and Lytham is next upon my list, and the colour of the towns corresponds with that of the drainage area. Those five different places are supplied with water from a watershed in the valley of the Wyre, which is indicated by the yellow colour. They have a population of nearly 10,000, and their drainage ground is 1,100 acres. Preston has a population of 83,000, and they have a drainage ground appropriated to them for their own purposes almost entirely (for they have purchased the water rights there and do not give water compensation), which is indicated by the two purple patches, Preston being the purple circle and the two purple patches supplying them with water, and they are abundantly supplied. Burnley has a population of nearly 29,000, and they have 1,050 acres, as is shown upon the map. Then there is another place called the Nelson Local Board, and their drainage ground is given as 1,700 acres. I do not know what the Nelson Local Board is, but it includes a certain number of manufacturing villages to the north of Burnley. Then comes Blackburn, which is one of my own waterworks; the population is 63,000, and we have 2,860 acres of drainage ground, including the compensation water. We have just completed very considerable additions to the works, and there is an abundant supply of water. Darwen is a small manufacturing place of 14,000 people; they have nearly 1,000 acres of drainage ground marked yellow, and they are well supplied. Liverpool comes next. According to the census of 1861 they had a population of 444,000 persons, and they have 10,000 acres of drainage ground at Rivington, which is shown by a large patch of red, in addition to the wells which they have in Liverpool or close to Liverpool, from which a large quantity of water is taken for the supply of the town. Bolton has 70,000 inhabitants, and it has a very large amount of drainage ground by recent parliamentary enactment; the whole of the works not yet being carried out. The area is shown by a great extent of green, the whole of it not yet being appropriated; it is 12,220 acres in all, which is more than the land that is taken for Liverpool. Heywood is a place of about 13,000 inhabitants with a drainage ground of about 1,300 acres, shown by the brown patches. Oldham comes next, with a population of 72,000, and they get their water, including compensation water, from 2,565 acres, marked blue. Ashton and Staleybridge have a population of about 60,000; they get their water, including the compensation water, from an area of 1,776 acres (as is shown by the green patches). From a portion only of their land they have to give compensation water, as a part of it is free from compensation in kind. Then comes Wigan, with a population of nearly 38,000 and a drainage area of 2,200 acres, shown by the tract of purple land, on which there is only a small amount of rain, perhaps the lowest amount of rain and the worst drainage area of any of those which I have been alluding to. Bury has about 30,000 inhabitants and a drainage area of about 1,100 acres, also shown in purple. Then there are the towns of Haslingden and Rawtenstall, small manufacturing towns in the north of Lancashire, which have an abundant supply, the population being 15,000, and the drainage area over 2,000 acres. Then Manchester, with a population of about 500,000, has a drainage area of 19,000 acres, enclosed in a purple patch on the map, and they are abundantly supplied. There are some other reservoirs marked upon the map, the Rochdale Canal reservoirs, and the Leeds and Liverpool Canal reservoirs, which are marked purple. I have also marked Halifax as it came into the map, and it happened to be a waterworks which I am now constructing, and I have also shown the drainage ground of Dewsbury, in Yorkshire. I will leave the map with the Commission, and all the particulars are shown in this table which I will hand in (*delivering in the same*).

PARTICULARS of DRAINAGE AREAS appropriated to the Supply of Towns in Lancashire, with the Population of the Towns.

Name of Place.	Population according to Census of 1861.	Drainage Area appropriated to Water Supply.
		Acres.
Lancaster - - -	14,487	11,837
Fleetwood, Blackpool, and Lytham	9,896	1,116
Preston - - - -	82,985	3,380
Burnley - - - -	28,700	1,050
Nelson Local Board - -	—	1,700
Blackburn - - -	63,126	2,860
Darwen - - - -	14,327	966
Liverpool - - -	443,938	10,000
Bolton - - - -	70,395	12,220
Heywood - - - -	12,824	1,290
Oldham - - - -	72,333	2,565
Ashton and Staleybridge -	59,827	1,776
Wigan - - - -	37,658	2,200
Bury - - - -	30,397	1,100
Haslingden and Rawtenstall -	14,752	2,357
Manchester - - -	500,000	19,000
Leeds and Liverpool Canal Reservoirs - - - -	—	1,920
Rochdale Canal Reservoirs -	—	4,020
Halifax - - - -	80,000	7,536
Dewsbury, Batley, and Heckmondwike - - -	45,000	2,000

The produce of each 1,000 acres of the above drainage areas will vary from 1,250,000 to 2,250,000 gallons per day, out of which, in most cases, compensation to the streams has to be given, which is generally equal to about one-third of the total quantity capable of being collected.

In the map to which these tables refer the towns and their respective drainage grounds are shown in the same colours.

6489. Does the map show that the gathering ground and the district supplied are colored alike?—Yes. The towns with their respective drainage grounds are all in the same colour. The foot-note which I have already written is, "The produce of "each 1,000 acres of the above drainage areas will "vary from 1,250,000 to 2,250,000 gallons per day, "out of which, in most cases, compensation to the "streams has to be given, which is generally equal "to about one-third of the total quantity capable of "being collected." In the case of Wigan, for instance, which has the lowest amount of rainfall and the flattest land, the produce would not be more than 1,250,000 gallons for each 1,000 acres; whereas, in Manchester, and in Preston, and some of the higher parts, Halifax and others, the produce would be 2,250,000 for each 1,000 acres, out of which, in most cases, compensation to the streams has to be given, which is generally equal to about one-third of the total quantity capable of being collected.

6490. With regard to one or two of the towns in question, you stated that they were amply supplied with water, which observation had reference to the area of the gathering ground; what per-centage of acres to population do you calculate, taking the mean rainfall in those districts, would be equal to the requirements of the population?—That is very easily determined. Each 1,000 acres, if you collect 24 inches of rain from them and impound it for delivery, will give you 1,500,000 gallons of water per diem throughout the year.

6491. (*Colonel Harness.*) Is that calculation based upon results?—It is absolute, 24 inches of rain upon 1,000 acres collected amount to so much, and that divided by 365 days gives you 1,500,000 gallons per diem.

6492. Then it is a computation, not the result of experience?—It is as true as truth; it must be so. If you collect 24 inches of rain, that depth of water collected and impounded and delivered day by day will deliver for 365 days at the rate of 1,500,000 gallons per diem.

6493. But do they gather and store 24 inches of rain?—That is another question. They collect various quantities over the districts I have mentioned from about 18 inches to 36 inches; 24 inches would be less than the average collection from that district. If you take Preston, for instance, it has a population of 83,000 persons, and Preston is a town which does not use 20 gallons of water per head per diem, only 16 or 17; but if you take 20 gallons a day it wants 1,600,000 gallons daily, and the drainage area is 3,380 acres, and at 1,500,000 gallons, which they will much more than collect, because they will collect at least 30 inches of rain in the course of the year (and 24 inches of rain will give 1,500,000), the 3,000 acres will give you 4,500,000 gallons a day. They will have perhaps from 5,000,000 to 6,000,000 gallons at Preston for a population of less than 100,000, out of which they have to give a little compensation, I believe, but not much, because they have purchased nearly all the rights in the streams upon which their works are constructed. It happens that their streams are short streams before they get to the river Ribble, and they bought out those rights, and the river is a tidal river close to them, so that they have not been required to give compensation in water.

6494. (*Sir B. Phillips.*) What is the entire number of the population in the district included in your table?—About 1,500,000.

6495. (*Colonel Harness.*) Can you give the actual fact as to the rainfall and the quantity of water obtained for any of those districts?—Yes; I can give the quantity of water actually collected in Liverpool, in Manchester, in Halifax, and in several other places which are included in the table.

6496. (*Sir J. Thwaites.*) By "collected" do you mean for the purposes of distribution?—Yes, for the purposes of distribution after deducting waste. In Manchester we have an enormous quantity of waste water, and our works are not yet so completed as to enable us without some trouble to measure the quantity of water which runs to waste, although every now and then I do it for the purpose of getting accurate information. In a year, in which we had 45 inches of rain, we had collected or run to waste 33 inches, which shows a loss of 12 inches. In Liverpool they have collected on the average about 36 inches out of a rainfall of about 46 inches, that is taken from actual measurement, and calculated upon the average of several years; or if you take it for the year 1861, their rainfall was 46⅛ inches, and they collected 35¾, including what they impounded and what was run to waste. In 1862 the rainfall was 48½ inches, and they collected 40 inches. In 1863 the rainfall was 51 inches, and they collected 40¾ inches. In 1864 the rainfall was 39 inches, and they collected nearly 28 inches. I am not aware that I promised the Commission any further returns than those which I have now had the honour of handing in, and I believe they comprise all that the Commission were good enough to expect of me.

6497. (*Mr. Harrison.*) Before leaving the subject of the map which you have just put in, will you just state whether it does not clearly show that in the particular district of Lancashire to which it refers there is an abundant watershed which is still unoccupied for the purposes of the population?—The map itself will show that. I do not believe that there is one of the towns which I have named that may be said to have a deficient supply of water. Liverpool had a year or two ago, but they have got some extra powers which enable them to get over their present difficulties, and they are using a large quantity of water. Liverpool, perhaps, is the only one that I am aware of which may be said to have a deficient supply, and it was only owing to want of proper storage that they ran short two or three years ago. The map speaks for itself. The brown serpentine-looking colour shows the summit of the drainage ground east and west, and the coloured patches of appropriated ground are few and far between as compared with the whole extent of mountain country from which water might be collected.

6498. (*Sir J. Thwaites.*) You have put in a paper showing all the important towns in Lancashire, the smallest of which is Fleetwood, containing a

J. F. Bateman, Esq.

4 March 1868.

population of 9,896. How are all the minor towns, if they may be so described, or towns with populations less than that, supplied with water?—I think that the table contains most of the towns; but if we take the case of Manchester, Manchester has become the purveyor of water to all the surrounding small towns. Newton takes from it, Stockport a portion of its supply, Tyldesley, Worsley, and a great many other places of 3,000 and 4,000 inhabitants, all take their supply of water from Manchester. Manchester extends its pipes 20 miles from its service reservoirs for the supply of distant places. It also supplies Stretford and Bowdon and Altrincham, and, through the intervention of the Stockport waterworks, Alderley Edge. Again, Bolton supplies Farnworth, Hulton, and many other places; and so, through the great waterworks, nearly all the small places get a supply of water.

6499. (*Colonel Harness.*) Does the population attributed to Manchester in the table include those outlying places?—No, the population actually in Manchester and its surrounding district dependent upon the water supply is probably about 600,000, but as I could not give all those particulars I gave the census of the town itself. Manchester includes Salford.

6500. (*Chairman.*) You have taken Manchester as having a population, according to the census, of 500,000; I presume that is Manchester and Salford proper?—Yes.

6501. And the drainage area appropriated to its water supply you have taken at 19,000 acres; would those 19,000 acres represent the area which supplies Manchester and Salford alone with water, or would it include the other towns which Manchester furnishes?—It includes the other towns. The whole of the water which those 19,000 acres will give is something over 40,000,000 gallons per day; and when all our works are completed (we are still making reservoirs for holding the water), after giving compensation amounting on the average to about 13,000,000 or 14,000,000 gallons a day, we shall have for the supply of Manchester and the places dependent upon it at least 25,000,000 gallons a day.

6502. (*Sir J. Thwaites.*) What is the population of the county of Lancaster as compared with the population on that plan?—I could give that by referring to the census, but I have not it with me.

6503. Are there not a number of places of considerable importance in Lancashire not included in this list that are taking their supply from sources which are polluted by the discharge of the refuse of manufactories and sewage into the streams?—Very few, I think, if any. I think I know almost every town in Lancashire, and there are very few in the condition which you mention. There are some towns not included in the list which take their water from the new red sandstone on which they stand, and which, therefore, do not obtain it from gathering grounds; for instance, St. Helens and one or two places on the banks of the Mersey take their water by wells sunk into the new red sandstone, and they have no gathering ground. Ormskirk, again, is another place, and Southport is another place of the same sort. They get their water from the new red sandstone on which they are, or to which they are contiguous, and I think if you go over the whole of the towns in Lancashire I could almost answer for the condition of the water supply in every town, but I do not think there is one which obtains its supply from an impure source.

6504. Can you give us the population supplied with water taken from the new red sandstone?—I cannot do that. Liverpool takes nearly half its supply from the new red sandstone, that is 500,000 persons in round numbers to begin with, and I should think probably from 100,000 to 150,000 persons besides in Southport, Ormskirk, St. Helens, and one or two of the new places on the banks of the Mersey. I should think from 600,000 to 700,000 persons would take their supply wholly or in part from the new red sandstone.

6505. (*Sir B. Phillips.*) Did I correctly understand you to say that 1,000 acres would give 1,000,000 gallons of water?—From 1,250,000 to 2,250,000. 1,000 acres, from which 24 inches of rain could be collected and stored, would give you 1,500,000 gallons of water daily.

6506. Then the storage of the water at Manchester is considerably more than 24 inches?—Yes; we can collect certainly 33 inches in the driest year in Manchester.

6507. You have a drainage area of 19,000 acres, I think I understand you to say, and you have 40,000,000 gallons of water per day?—In Manchester each 1,000 acres would contribute upwards of 2,000,000 gallons of water per day, in fact 2,250,000.

6508. What is the rainfall there?—The rainfall, taking a dry year, would be something more than 40 inches, and taking the mean of three dry years we can collect 33 inches. The mean rainfall is a little under 50 inches.

6509. (*Chairman.*) Is it your opinion that Lancashire is at the present moment very well supplied with water?—Yes, it is; as a whole it is well supplied with water. Of course the population is so constantly increasing that they have to come frequently for extensions of works, but Manchester has a supply for a long period. Liverpool is using a great deal of water, and they are speaking of going to Bala Lake or getting an additional supply from the new red sandstone. Preston is abundantly supplied; Bolton is most abundantly supplied; Lancaster is abundantly supplied; Blackburn is well supplied, and all the places mentioned in that table, without exception, are well supplied for their present wants. Of course I do not say that in the course of the next 10 or 20 years they may not have to come to Parliament for further power; most likely they will.

6510. (*Mr. Harrison.*) If they are obliged to do so there is abundance of water to be got, is there not?—There is a great deal of water still to be got.

6511. (*Sir J. Thwaites.*) That additional power has reference, has it not, rather to the works than to the gathering ground?—And to the gathering ground also. They will have to go for more gathering ground. For instance, we shall have 25,000,000 gallons a day at command when our works are completed for the Manchester districts; but so soon as we approach anything like a demand upon us for 20,000,000 gallons we ought to go to Parliament for further gathering ground, because the construction of works takes such a time that we always ought to be at least five years ahead of the demand upon us.

6512. Apart from the statutory power you consider that you have ample gathering ground in Lancashire to supply its inhabitants with water?—I think so at present and for a long time to come.

6513. (*Chairman.*) Are there any statements which you made when you were formerly examined which you would desire to correct or explain?—There are. My survey of the country with reference to fixing the district and the reservoirs was made in the years 1860, 1861, and 1862, and at that time the railway in the Dulas Valley was not constructed. In the pamphlet which I wrote in 1865, and in the evidence which I subsequently gave with regard to the Dulas district, which is represented by this green patch to the south of that red reservoir on the map, I stated that that district had not been surveyed with reference to reservoirs, but that from a cursory examination of it it seemed as capable of affording sites as any other district. Between the time at which my survey was made and the time at which I wrote that pamphlet and gave evidence here, a railway was made through that valley, which destroyed the best sites for reservoirs; I find now that they could not be made there, or they could not be made certainly with the same advantage which I had previously considered. I was not aware of the fact of the railway being made, and therefore that was a misstatement which I made at the time I gave evidence before you.

6514. (*Sir J. Thwaites.*) If you are deprived of that valley now occupied by the railway, where do you propose to place your reservoirs?—There are sites in abundance. There is a very good site

which is marked upon the map, at a place called Babylon, and there is another large reservoir at the head of the Wye which can be taken into it, with an additional drainage ground; and there are various other sites for reservoirs probably not quite so favourably situated as they would have been if it had not been for the railway. There are two magnificent sites above Trefeglws, where reservoirs might be constructed at a level so as to receive the whole drainage water of this district, so that there are plenty of sites for making reservoirs.

Again, there was some statement made with reference to the lead workings, that there were more lead workings than I had given credit for, and that seems to have been so, inasmuch as some workings have been discontinued which were working at the time that I made my examination, and in other places others have commenced. I cannot do better than leave that question in the hands of Mr. Whalley, who knows the country perfectly, and has given evidence, and of Dr. Pole, who has examined the country, and can speak to the actual fact.

6515. How would you deal with those lead workings if they are more numerous and more extensive than you calculated upon?—They do not appear to be so. Some have been abandoned and others have been started, but they do not seem more numerous nor more extensive than they were.

6515*a*. You were under the impression when you gave your evidence upon the last occasion that some of those lead mines were out of working, and you have found that they are now in working?—There are some workings which have commenced in the interval between my examining the ground and publishing my pamphlet, and others have been discontinued; but I do not think that they are more numerous, or that there is a larger amount of lead working, taking the balance, than there was at the time when I examined the district. For instance, at the time I made my first survey, I abandoned that large portion of the river Severn proper, which is covered with green strokes on the map, because there were lead workings in it; but those lead workings have been discontinued, and the water is exceedingly good which comes from there; in fact, some of the best water and most abundant water that is available for collecting. In the place of the lead workings which have been discontinued other works have been commenced at other places, but it seems from the evidence which has been laid before you that no contamination of the water arises, that no lead is discovered, that the grosser particles may very easily be intercepted by subsiding reservoirs, as has been done, and that the finer parts of the material which is carried down from the washing are of real service to the water. The report of Dr. Frankland, which I had the privilege of reading, gives a most lucid, clear, and full description of all those circumstances. Therefore I prefer making no observation myself upon that subject, but would leave it to the information which has been obtained for the Commission by Mr. Pole, and to the chemical analyses of Dr. Frankland.

The next point, which seemed to be rather misunderstood, was, that I spoke of 1865 as the driest year. I spoke of it as the driest year with reference to the particular tables to which I was then alluding; and although it was almost the driest year of which we had any record, it was not absolutely so except with reference to the particular tables. But although it was not the driest year in point of rainfall, it was in most parts of the country the severest year with reference to the amount of water which was collected in all those districts where the supply of water depends very much upon springs. It was a more severe year than 1864, which was a drier year in point of amount of rainfall. In the Manchester waterworks we had a longer drought and a severer year in 1865 than we had in 1864. This diagram (*handing the same to the Commission*) represents the amount of storage at any one time in a certain number of years in the Manchester waterworks. At the commencement of 1864 the reservoirs were not as full as they were shortly after the commencement of the year 1865; they go down irregularly to a comparatively low level, and in the course of 1865 they go down to a still lower point and for a much longer period, and you will find over the whole of that diagram no drought so severe as the drought which occurred in 1865. The diagram does not represent the water falling in rain, but the water in store. In a great many of our reservoirs the greatest depth of water is about 80 feet, and at that time, in 1865, we had 1,012,000,000 gallons in store; at the lowest period, in 1866, we had 2,068,000,000 gallons in store; and in 1867 the lowest we came to was 2,384,000,000 gallons. I also have to correct a statement with reference to the drainage area, which is the only real inaccuracy of which I believe I have been guilty, and that has been a mistake of a figure. It was stated that the Thames drainage down to Kingston was erroneously stated, and it is so by an amount of 400,000 acres. Instead of being in round numbers 2,740,000, which I believe is the quantity given, it is really 2,340,000. I do not know how the mistake was made. I make it by a fresh calculation 2,382,400. Again, it was stated that I had over-estimated the drainage area of the Severn to Tewkesbury. Tewkesbury is below the junction with the river Avon, and the area, which I correctly stated in my evidence and in my pamphlet, includes the drainage of the Avon, which is about 628,000 acres. That added to the area which was stated by the other gentlemen will bring it up to the same figure as nearly as possible.

I believe there are no other statements that I wish to refer to except one as to the volume of water in the Thames in extreme drought, which seemed to be doubted. I did not gauge the Thames quite at its lowest point, but it was as nearly so as possible, and for several days it did not vary. It was measured on the 21st of September 1865. The river was measured in sections by wire ropes being strung tightly across the river at various places and distances marked upon them, and the depths were taken so as to indicate exactly the bottom of the river, and then by floats the velocity was taken in five or six different places by taking the time in which the floats went from one wire to the other. The velocity was not computed from the superficial velocity, but was actually ascertained by floats so adjusted that whilst one all but dragged upon the bottom and therefore showed the bottom velocity, another floated upon the surface and showed the surface velocity, or rather the one acted upon the other in quickening and retarding their respective paces. Gutta-percha is usually employed by me for gauging the velocity of streams. It is very nearly of the same specific gravity as water, being ·96 of water, and therefore it floats. A gutta-percha ball will float almost wholly immersed, so that the wind can have no effect upon it. The balls were so adjusted that one was heavier than the other and sunk to the bottom, but did not touch the bottom. Having ascertained the depth we adjusted it by a length of rope, which was attached to another ball, which floated upon the surface, and so we got the actual mean velocity. The place at which it was measured was just above the three pumping stations of the West Middlesex, the Grand Junction, and the Southwark and Vauxhall Companies at Hampton, and the total quantity of water was 308,720,000 gallons on that date. Nothing could have been more carefully done, and I am quite sure that that is as accurate a measurement as ever was taken of the quantity of water which is discharged in the Thames.

6516. (*Sir J. Thwaites.*) I presume careful sections of the river were made at that part where you gauged it?—Yes.

6517. You make the minimum flow considerably less than Mr. Simpson?—I know I do; but I do not think that it was ever measured with such accuracy before, or that he did it in the same way. But Mr. Simpson takes his supply from the river at Thames Ditton, at a point which is below the river Mole, and therefore he gets the river Mole in addition.

J. F. Bateman, Esq.

4 March 1868.

6518. Did not Mr. Hawksley give evidence very much to the same effect, that the quantity was about 350,000,000?—I do not know whether Mr. Hawksley himself measured it, but Mr. Simpson's measurements are at Thames Ditton and include the Mole, which gives a very inconsiderable quantity in dry weather; but some additional quantity of water comes in between the two points of measurement, and therefore the quantity ought to be larger.

6519. Did you ascertain the mean flow?—No. I was only anxious to ascertain the minimum, the mean flow you can hardly possibly get.

6520. (*Mr. Prestwich.*) Do you think that the Mole would account for that difference?—No, it would not fully account for the difference.

6521. (*Sir J. Thwaites.*) During how many days was this gauging made?—The actual velocities were taken in one day; the preparation took several days in getting all the lines across, and all the sections; but the velocities were all taken in one day. Wire ropes were put across and staked, and the points marked and levels taken, and so on; then the velocities would be all taken in one day, so as to be all exact on that one day. I may mention that in large rivers and open watercourses I have worked constantly with Eytelwein's rule, and I have always found it as nearly as possible correct; and Du Buat's rule also in open watercourses, where we have a tolerably uniform section, is as nearly as possible absolutely correct.

6522. Supposing you had a very high wind, would not that have mastered the retarding influence at the bottom?—We should not have ventured to have taken the observations in a high wind; it was a calm day, otherwise we should not have ventured to run the risk of the possibility of error. The lower ball would not be influeuced by the wind, but the upper ball might be influenced by it.

6523. (*Chairman.*) Is there any other statement which you wish to correct?—I think there is no other which occurs to me.

6524. With regard to the rain returns that is the next point, is it not, to which you wish to call the attention of the Commission?—Yes. I am very anxious that the Commission should bear with me a little while I explain all that as clearly as I can. I ventured to make the statements which I did, not at hazard, but after a very careful consideration of the circumstances of the country and the information which I had been able to collect, that the rain upon this portion of Wales would be as great as in Cumberland in similar localities, and in the district surrounding Loch Katrine. I stated that the rain would be on an average from 70 to 80 inches, that 60 inches would be the rain on the average of two or three consecutive dry years, and that we might safely depend in such years upon collecting 48 inches. I did not take 48 inches in estimating the quantity of water which we could collect, but, if you remember, I took 36 inches, which gave from the storage which we have 220,000,000 gallons of water per diem, and then by adding about half a foot a second for the quantity of spring water which would be yielded on an average during a long drought, equal to 30,000,000 gallons a day, we should have a supply for 120 days of 250,000,000 gallons beyond doubt. I am anxious to show the Commission that every one of those statements was almost absolutely correct. If you refer to the evidence, I took, if you remember, nine gauges in Cumberland and Westmoreland, which I selected for the purpose of comparing as nearly as I could with nine gauges under as nearly similar circumstances as I could select them in the Welsh district—gauges which had been kept independently of any of my own; and it showed that in each district those gauges were within less than an inch the same. The advantage in point of position I considered to be with the Cumberland gauges as likely to show a larger amount of rain than those in Wales; but it so happened that in the year 1865, which was the year I took, the rain was in both cases on an average throughout 59 inches. Last year, 1867, I have taken the returns out for both the gauges in Wales and in Cumberland, which I then selected, and I find that the rain last year in Cumberland was two per cent. less than the mean rain of 22 years in the Cumberland district, taking Mr. Symons's standard gauges which are at Seathwaite at the head of Borrodale, the How in Troutbeck and Keswick, where observations have been continued, as he gave evidence last year, for 22 years, and therefore he determined by reference to the mean of that lengthened period whether any particular year was above or below an average; taking the same mode of proceeding, and taking the same gauges, I found that the Cumberland gauges were two per cent. below the mean rain of 22 years. In the Welsh gauges I have to add 10 per cent., because the only gauge which has been continued for any period, the only one which has any reference to this mountain range is, the Rhyader gauge. The rain last year was 10·18 per cent. less than the mean of 10 years during which this gauge has been kept. Therefore I have to add to the returns in Wales 10 per cent. to bring them up to the mean rain, that is to say, to what would be the rainfall at those particular gauges if it had been a year of mean rainfall. Having premised that in order to show the Commission the way in which the thing has been worked out, I will show you that the mean rainfall in Cumberland of those nine gauges, which are Keswick, Scawfell Pike, Derwent Island, Great End, Brant Rigg, Esk Hawse, Ambleside, Patterdale Hall, and Wasdale Head, varying in height from 250 to 3,200 feet above the level of the sea, was 72·77 inches, and adding two per cent. in order to bring it up to what would be the year of mean rainfall it comes to 74·27 inches. And as to the actual rain in Wales, the mean of the rainfall at Dolgelly, Trawsfynnyd which is above Dolgelly, Festiniog, Rhiwbryfdir, Beddgelert, Bettws-y-coed, Llanberis, Rhayader, and Llanidloes, Llanidloes being a place within the district, at heights varying from 70 feet to 1,140 feet above the level of the sea, and therefore very much inferior in height to the Cumberland gauges, the actual rain upon the average of all those was 67·92 inches, and adding 10 per cent. in order to bring them up to a year of mean rainfall, they came to 74·71 inches against 74·27 inches. I also stated that the rain in my own district, if I may call it so, would be as great as the rain of the district selected by Mr. Hemans and Mr. Hassard, or nearly so. Eight gauges were put down in that district under the care of Mr. Symons for the purpose of determining the amount of rain, and the actual rain upon the average of those eight places is 75·77, and adding two per cent. in order to bring it up to the mean rainfall it would be 77·27. Then, taking six gauges in my own district compared with eight in the other, the actual rain last year, 1867, at the gauges in Wales over the whole district proposed to be appropriated was 67·57, and adding 10 per cent. to that in order to bring them up to a year of mean rainfall, it comes to 74·32 against 77·27 in the Ulleswater district. I have already stated that I believe that the rain in the Welsh district would be as great as the rain in the Loch Katrine district. I find that some of the mountain gauges on Loch Katrine have been discontinued from the difficulty of attending to them, and the manner in which they are frozen, and so on, and therefore I am obliged to make a selection of those which as nearly as possible represent the mean rainfall; five of them may be taken to do so, and the mean rainfall in 1867 of those five gauges was 72·64 inches. Those places are Loch Dhu, Loch Drunkie, Loch Venachar, the hill above the Loch Katrine tunnel, and Glengyle, Glengyle being at the head of Loch Katrine, and showing as large or larger an amount of rain, although it is a valley gauge, as falls upon the high lands. The mean rain of those same gauges, taken over periods varying from seven to 14 years, is 77·34 inches. Therefore this year, 1867, was about seven per cent. less than the mean rainfall. Now taking the mean rainfall you have this state of things, that the nine gauges in Cumberland which I took for the purpose of determining the question before I

had any other facts before me, show a rainfall of 74¼ inches, whereas the Welsh gauges, which I took as corresponding gauges, show a rainfall of 74¾ inches; the gauges on the Ullswater district proposed to be taken for London show a rainfall of 77¼ inches. The gauges of my own Welsh district show a rainfall of 74¾ inches, and the rainfall of the hills round Loch Katrine, in Scotland, appears to be 77⅓. They are all between 70 and 80 inches, which was the statement I made with reference to that subject. Perhaps the Commission will allow me to hand in some tables which I have prepared, showing the rainfall in the Welsh district upon which my calculations are founded.

TABLE showing the RAINFALL in the District in NORTH WALES proposed to be appropriated for the Supply of the Metropolis, from October 1st, 1866, to December 31st, 1867.

Months.	No. 1. S.W. of Llanidloes. Elevation above O.D. 950 feet.	No. 2. Head of the River Clwyedog. Elevation above O.D. 1,300 feet.	No. 3. In the Valley at Carno. Elevation 550 feet above O.D.	No. 4. On hills at Can Office. Elevation above O.D. 1,100 feet.	No. 5. In the Valley at Llanwddyn. Elevation above O.D. 720 feet.	No. 6. On Hills at the head of the River Vyrnwy. Elevation above O.D. 2,000 feet.
1866.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
October -	13·7	24·9	12·5	18·3	16·5	24·8
November -						
December -						
1867.						
January -	20·4	14·1	39·3	16·0	32·3	23·9
February -				8·0		
March -				8·2		
April -	4·1	23·6		1·6	5·9	18·0
May -				6·9		
June -	6·2				5·5	19·4
July -	1·0	22·5	4·0	8·4	7·5	
August -	5·3		8·0			
September -	5·3		5·0		9·2	
October -	1·1	24·5	3·0	14·8	1·9	20·4
November -	3·5		6·5		5·1	
December -						
Totals for the 15 months -	60·6	109·6	78·3	77·2	83·9	106·5
Totals for the year ending Sep. 30, 1867	50·7	85·1	63·8	62·4	67·7	86·1
Totals for the year ending Decr. 31, 1867	46·9	84·7	65·8	58·9	67·4	81·7

TABLE showing the RAINFALL at the four old-established GAUGES in WALES, adopted by Mr. SYMONS, for the several 12 Months ending September 30th in each Year up to September 30th, 1866,—the MEAN ANNUAL RAINFALL for this period,—the RAINFALL for the 12 Months ending 30th September, 1867,—and the PROPORTION which it bears to the preceding Observations.

Years. 12 months ending Sept. 30th.	Rhayader. Elevation above the Sea 880 feet.	Lampeter. Elevation above the Sea 450 feet.	Hawarden. Elevation above the Sea 270 feet.	Maes-y-dre. Elevation above the Sea 400 feet.
	Ins.	Ins.	Ins.	Ins.
1856	—	39·64	24·90	—
1857	—	45·38	29·80	—
1858	—	31·46	19·40	—
1859	48·15	42·39	29·00	25·92
1860	60·62	59·31	28·04	30·09
1861	43·18	41·31	23·63	19·09
1862	45·38	46·12	29·28	22·35
1863	43·02	43·01	20·24	25·47
1864	37·67	36·69	25·25	24·34
1865	39·50	38·17	21·87	21·67
1866	52·29	55·95	29·61	26·75
Mean - -	46·23	43·58	25·55	24·46
12 months ending Sept. 30, 1867 - -	44·88	39·03	25·86	23·65
Proportion which rainfall of 12 months ending Sept. 30, 1867, bears to mean of preceding observations -	3·008 per cent. less than "mean."	11·65 per cent. less than "mean."	1·25 per cent. more than "mean."	3·42 per cent. less than "mean."

Average 4·79 per cent. less than "mean."

TABLE showing the RAINFALL at the four old-established GAUGES in WALES, adopted by Mr. SYMONS, for the Years up to and including 1866,—the MEAN RAINFALL to that time,—the Rainfall of the Year 1867,—and the PROPORTION which it bears to the Mean of the preceding Observations.

Years.	Rhayader. Elevation above the Sea 880 feet.	Lampeter. Elevation above the Sea 450 feet.	Hawarden. Elevation above the Sea 270 feet.	Maes-y-dre. Elevation above the Sea 400 feet.
	Ins.	Ins.	Ins.	Ins.
1855	—	32·37	21·80	—
1856	—	41·02	25·90	—
1857	—	40·00	28·10	—
1858	35·11	36·69	21·70	21·57
1859	50·72	45·82	30·50	28·02
1860	59·52	55·30	27·80	29·00
1861	40·73	43·98	21·82	17·01
1862	47·81	43·22	30·37	24·09
1863	42·72	45·38	23·06	28·98
1864	37·02	32·58	21·67	21·19
1865	41·48	42·39	21·96	21·22
1866	51·05	50·86	29·82	26·93
Mean - -	45·13	42·47	25·375	24·22
1867	40·96	42·62	27·41	24·77
Proportion which rainfall of 1867 bears to mean of preceding years	10·18 per cent. less than "mean."	0·353 per cent. more than "mean."	8 per cent. more than "mean."	0·227 per cent. more than "mean."

Average 1·06 per cent. less than "mean."

TABLE showing RAINFALL in the DISTRICT proposed to be appropriated for the SUPPLY of the METROPOLIS for the periods of 12 Months ending September 30th, 1867, and 12 Months ending 31st December 1867, respectively, with the Correction to determine approximately the AVERAGE RAINFALL of the District deduced from the results of the Rainfall at RHAYADER for these several periods.

Gauges in the Welsh District proposed to be appropriated for the Supply of the Metropolis.	Actual Rainfall during the 12 months ending Sept. 30, 1867.	Approximate Mean Rainfall determined by adding 3 per cent.,—the difference between the Rainfall at Rhayader for this period, and the Mean of the preceding 8 years ending Sept. 30, 1866.	Actual Rainfall during the 12 months ending Decr. 31, 1867.	Approximate Mean Rainfall determined by adding 10 per cent.,—the difference between the Rainfall at Rhayader for this period, and the Mean of the preceding 9 years ending Decr. 31, 1866.
	Ins.	Ins.	Ins	Ins.
No. 1, S.W. of Llanidloes	50·7	52·221	46·9	51·59
„ 2, Head of River Clwyedog -	85·1	87·653	84·7	93·17
„ 3, Valley at Carno -	63·8	65·714	65·8	72·38
„ 4, Hills above Can Office -	62·4	64·272	58·9	64·79
„ 5, Valley at Llanwddyn -	67·7	69·731	67·4	74·14
„ 6, Hills at head of River Vyrnwy -	86·1	88·683	81·7	89·87
Mean of all the gauges -	69·3	71·38	67·56	74·32

The two "approximate means" of all the gauges as above, give a mean of 72·85 inches, or about 73 inches.

STATEMENT showing the DISTRIBUTION of RAIN over the WELSH DISTRICT as determined by the GAUGES put down by Mr. BATEMAN.

The rain gauges put down and the returns for the 12 months ending December 31, 1867, are shown in the following table. The *average* rainfall is approximately determined by adding 10 per cent. to the "actual" rain.

Position of Gauges.	Elevation above the Sea.	Actual Rainfall during the 12 months ending Decr. 31, 1867.	Approximate Mean Rainfall determined by adding 10 per cent. to "actual" rain.
	Feet.	Ins.	Ins.
No. 1, S.W. of Llanidloes -	950	46·9	51·59
„ 2, Head of River Clwyedog	1,300	84·7	93·17
„ 3, Valley at Carno -	550	65·8	72·38
„ 4, Hills above Can Office	1,100	58·9	64·79
„ 5, Valley at Llanwddyn	720	67·4	74·14
„ 6, Hills at head of River Vyrnwy - -	2,000	81·7	89·87
Mean of all the gauges -	—	67·56	74·32

J. F. Bateman, Esq.

4 March 1868.

Vyrnwy and Banw District.

Llanwddyn or Vyrnwy District.—Drainage area, 22,352 acres.

Gauges Nos. 5 and 6 are situated in this district and represent the rainfall on the lower and higher portions of the drainage ground respectively, the lower portion forming one-third and the higher portion two-thirds of the whole.

The mean rainfall of the district will therefore be the mean between the rainfall at gauge No. 5, and twice the rainfall at gauge No. 6, as follows:—

	Actual Rain for the 12 months ending Sept. 31, 1867.	Approximate Mean Rainfall.	Mean of the District.
Gauge No. 5; elevation 720 ft.	67·4	74·14	74·14
Gauge No. 6; elevation 2,000 ft.	81·7	89·87	89·87 89·87 ÷3 = 84·63 ins.

Banw District.—Drainage area, 44,028 acres.

The only guage in this district is No. 4, on the hill above Can Office. Gauge No. 6 is, however, within two miles of the summit of the drainage ground, and it will represent the rainfall on the higher portion which forms one-fourth of the drainage area. Gauge No. 4 will represent the middle level of the district, which forms one-half of the whole, and on the remaining one-fourth of the drainage area, being the lower portion, a less rainfall will obtain, and it has been assumed that gauge No. 1, above Llanidloes, will approximately represent the rainfall of this level.

The mean rainfall of this district is determined as follows:—

	Elevation above the Sea.	Actual Rain for the 12 months ending Decr. 31, 1867.	Approximate Mean Rainfall.	Mean of the District.
	Feet.	Ins.	Ins.	Ins.
Gauge No. 4	1,100	58·9	64·79	64·79
Do. „ 6	2,000	81·7	89·87	64·79 89·87 ÷4 = 68·75 Ins.
Do. „ 1	950	46·9	51·59	51·59

Summary for Vyrnwy and Banw District.

	Drainage Area.	Mean of the District.
Llanwddyn or Vyrnwy District	22,352 acres	84·63 ins.
Banw District - - -	44,028 acres.	68·75 ins.
Total - - -	66,380	Mean 74·09 ins.

River Severn District.

River Carno District.—Drainage 17,289 acres.

The only gauge in this district is No. 3, in the valley at Carno. For the higher level of the drainage ground, which forms one half of the whole, it has been assumed that a mean of gauge No. 3 and of gauge No. 2, at the head of the river Clwyedog, about 3½ miles distant, will represent the rainfall. For the lower level, which forms the other half of the drainage area, the gauge No. 3 will represent the rainfall.

The mean rainfall of this district is therefore as follows:—

	Elevation above the Sea.	Actual Rainfall for the 12 months ending Decr. 31, 1867.	Approximate Mean Rainfall.	Mean of the District.
	Feet.	Ins.	Ins.	Ins.
Gauge No. 3	550	65·8	72·38	72·38 93·17
				165·55
Do. „ 2	1,300	84·7	93·17	82·775 72·38 ÷2 = 77·57 Ins.

Rivers Dulas, Twlch, and Afon Brochan District.—Drainage area, 15,139 acres.

The only gauge in this district is No. 1 in the valley to the S.W. of Llanidloes. The higher portion of the district, forming one half of the whole, is similarly circumstanced to the higher portion of the Carno district, and for this area the same mean rainfall, 82·775 ins., will apply. For the lower portion, which forms the remainder of the district, the gauge No. 1 will represent the rainfall.

The mean rainfall of this district will therefore be as follows:—

	Elevation above the Sea.	Actual Rainfall for the 12 months ending Decr. 31, 1867.	Approximate Mean Rainfall.	Mean of the District.
	Feet.	Ins.	Ins.	Ins.
Gauge No. 1	950	46·9	51·59	51·59 82·775 ÷2 = 67·18 Ins.

Rivers Clwyedog, Tarannon, and Ceryst District.—Drainage area, 31,764 acres.

The rain gauge in this district is situated at the head of the river Clwyedog, and this gauge will represent the rainfall on the highest level of the drainage area, which forms one-third of the whole. For the lower range of hills which flank the drainage to the north and south, and are similarly situated to the hill portion of the Carno district, the mean rainfall of that district will apply. The rainfall on the lower level of the drainage ground and the valleys will be represented by gauge No. 1. The three levels are approximately equal in area.

The mean rainfall of the district will therefore be as follows:—

	Elevation above the Sea.	Actual Rainfall for the 12 months ending Decr. 31, 1867.	Approximate Mean Rainfall.	Mean of the District.
	Feet.	Ins.	Ins.	Ins.
Gauge No. 2 -	1,300	84·7	93·17	93·17
Gauge No. 1 -	950	46·9	51·59	51·59 ÷3 = 75·51 Ins.
Hill gauge for Carno district, mean of Nos. 2 and 3	- -	- -	82·775	82·775

Summary of Severn Proper District.

	Drainage Area.	Mean Rainfall of District.
	Acres.	Ins.
Carno district - - -	17,289	77·57
Dulas, Twlch, and Afon Brochan district - - - -	15,139	67·18
Clwyedog, Tarannon, and Ceryst district - - - -	31,764	75·51
Total -	64,192	mean 75·09
Vyrnwy and Banw district, total -	66,380	mean 74·09
Both districts, total - -	130,572	mean 74·58

	Ins.
Mean rainfall of district - - - -	74·58
Deduct one-sixth, to obtain mean of three consecutive dry years - - - - -	12·43
Mean rainfall of three consecutive dry years -	62·15
Deduct for loss, say - - - -	12·15
Available rainfall or average of three consecutive dry years - - - - -	50·00

I am obliged, reluctantly, to make observations upon some evidence which was given with regard to what was likely to be the rainfall, and what was likely to be the produce, because upon that of course very much depends, and I am obliged to refer to the evidence of Mr. Symons. Mr. Symons gave evidence before the Commission on two days. He grounded the results which he arrived at on the observations that I was enabled to give him of three

complete months, the last months of 1866, and he compared the rainfall with the rainfall in the Ullswater district for the same period. The rain in the Ullswater district was 31 inches, the rain in the Welsh district was 19 inches, and he came to the conclusion that it was a rule-of-three question. The mean annual rainfall he reduced for the Cumberland district to 77 inches, and in that respect I must give him credit for being very near the truth, because the mean rainfall of those gauges was 77¼ inches, therefore he was remarkably correct in deducing that rainfall. And he put it in this way: as 31 inches in Cumberland were to 19 inches in Wales, so 77 inches would be to the gross amount of rain in Wales, that is to say, to 47 inches as the average rain in Wales. But he omitted to draw your attention to the effect of a statement that he made that in the lake district the three months rain was 24 per cent. above the average, and in Wales it was only 17 per cent., taking Lampeter, Rhayader, and Hawarden as his guides. Then he ought to have deducted 24 per cent. from 31 inches, and 17 per cent. from 19 inches, before he was able to put this equation as a rule of three question. 31 inches minus 24 per cent. is 23½, and 19 inches minus 17 per cent. is 16 inches, so that it should have stood thus: as 23½ are to 16 so are 77 to the result, which in that way would be 52 inches instead of 47 inches. But why does he take Lampeter and Hawarden? He might as well take London and Paris; they are quite away from the mountain range, and they cannot be supposed to indicate the rain in the hill district any more than Sowerby Bridge, on the eastern foot of the backbone of England, can indicate the rain upon the tops of the hills or the ratio. If he took Rhayader, which I have not the slightest objection to his doing, it being very near to my district, the Rhayader gauge was only 13 per cent. minus, on the average of nine years I think it was, so that from 19 inches only 13 per cent. should be deducted, making 16⅓, and it then would read thus: as 23½ inches are to 77, so 16⅓ would be to the result, which would be 54. So that taking his own figures properly used, the result would have been, according to his figures, 54 inches instead of 47 inches. As he has taken it, Mr. Symons said that he thought the thing was wrong, although he could not see where it was wrong, but he believed there was more rain. I have merely taken the Commission through this calculation for the purpose of showing that his own figures properly handled produce a very different result from that which he laid before you. I may now mention to you what the actual state of things is. After having carefully considered the whole question, and appearing again before the Commission, Mr. Symons came to this conclusion, that the mean rain would be 60 inches, but considering special circumstances he assumed it to be 55 or 56 inches. Now the special circumstances, as far as I understand his evidence, are, that five-sixths of the gathering ground would be represented by the valley gauges, being low land, and that only one-sixth would be high land and fairly represented by the high gauges. He is entirely wrong there, as I have shown in the preceding tables. The gauges were put down for the purpose of representing as nearly as they could the average amount of rain, and by carefully considering the altitudes of the various districts and appropriating the amount of rain according to the altitude, the result is that the rain for the year ending 1867 in the Welsh district, corrected for mean rainfall, being 74·32 inches, and the mean rain according to elevation of ground being 74·58, the difference is less than half an inch, so that the rain-gauges which I put down do exactly what they were intended to do—that is to say, they represent the mean rain over the whole district. Mr. Symons then gave you a table of what he considered to be the "*true mean*," as he called it, of the district under consideration, and he gave the rain in the valley south-west of Llanidloes as 48·39, whereas the actual rain was 50·7. On the hills above Llanidloes he gave the true mean 80·32; the actual rain was 85·1. In the valley at Carno he calculated that it would be 40·32; it was 63·8. On the hills near Can Office he estimated the rain at 59·13; it was 62·4. In the valley at Llanwddyn he estimated 52·68; it was 67·7. On the hills above Llanwddyn he estimated the rain at 80; it was 86·1. The mean of his estimated result was 60·14; the actual state of things was 69·3. That was for the year not ending December 31st, 1867, but September 30th, 1867, which included the three months to which he had specially directed his attention; the rain of that period was only three per cent. less than the mean rain, and therefore I have to add to that amount three per cent., which brings up the rain corrected in that way to 71·38, instead of 60·14. The year ending the 31st December, 1867, shows a rainfall, corrected so as to bring it to a mean rainfall, of 74·32, the mean of the two being 72·85, in round numbers 73 inches. I have laboured this perhaps rather more than is interesting to the Commission, but I was anxious to show that the figures which I have given you are really figures which I am now able to lay before you with confidence. These are actual results corrected in the way I have shown you, and I was quite justified in taking the average rain at an amount of between 70 and 80 inches, and the minimum rain of three consecutive dry years at 60 inches. Adopting the rule which has been stated before you, and which, although it is not universally true, yet is sufficiently near the truth to be adopted, that the mean of three consecutive dry years is one-sixth less than the average rainfall, thus if from 73 inches (if you take the year ending the 30th of September), or 74 (if you take it as ending the 31st of December), you deduct one-sixth, that leaves you 61 or 62 inches, according as you take the one or the other, as the mean of three consecutive dry years. If you deduct from that 12 inches as the amount of loss by absorption and evaporation, which is a full amount in this district, you have 49 or 50 inches, as you take the one or the other year, as the residual quantity of water which you may collect in reservoirs in the driest years. I have only taken it for the purpose of calculation before you at 36 inches, plus springs, which brings it to about 40 inches. I need not pursue that further, but I must now give you the amount of loss which I have stated at 12 inches. I will give it from some tables which give the annual loss in various places. In Liverpool I have already stated the result of 1861, 1862, 1863, 1864, and 1865 in answer to a question of Sir John Thwaites, showing that the mean loss there is about 10 inches out of a rainfall of some 47 inches. The average rainfall of the five years taken together was 46¼, and the amount collected was 36·10, therefore the loss was a trifle more than 10 inches in the year, and that is from a small rainfall. In Sheffield, where some years ago they had reservoirs so large that they could not fill them, and therefore they made the best possible gauge basin in the world, and where the rain is received from a tract of flat moor land, they had an average amount, over a great number of years, of 39½ inches, and they collected 25 inches from those flat-topped hills which are covered with peat, and which are therefore liable to considerable loss from absorption and evaporation, showing a loss of 14½ inches. At the Gorbals waterworks, which now form part of the Glasgow waterworks, the quantity of rain and the amount of loss were very accurately observed for many years, and the mean loss on a considerable number of years was 10¼ inches. I could mention others, but those are the most certain returns that I could refer you to. I may, perhaps, mention one other return, which is the case of Newcastle-upon-Tyne, the Whittledean waterworks, where the rainfall is excessively small, and where the drainage ground is very flat and highly cultivated, and therefore the loss may be considered to be likely to be very much. In the year 1850 they had only 17⅔ inches, and they got only 6⅓ into their reservoirs, their loss being 11·13. In 1851 they had 21⅓ inches of rainfall; they collected 8 inches, and the loss was 13⅓. Therefore upon all

J. F. Bateman, Esq.

4 March 1868.

those returns I think I am justified in saying that 12 inches is more than enough to deduct, so that I hope I have made good my ground that the rainfall is as much as I represented, and that we should be certainly able to collect more than 36 inches, that we might safely calculate upon 48 inches, and that therefore all the calculations which have been made by other parties which contravene these have been made without sufficient information and are erroneous.

6525. (*Mr. Prestwich.*) You have given us the mean of the three driest years; what do you estimate to be the rainfall of the driest year?—I should think that the rainfall of the driest year would probably be about 50 inches or a little more.

6526. Do you state that from recent gaugings that you have made in the driest year?—I cannot decide the driest year. The driest year will be less than the mean of three dry years, and I have taken the mean of three dry years, for where we have large storage reservoirs we do not require to take the driest year, because we have a stock in store which will help out a dry year; therefore if we get three dry years together we take the mean of three dry years, and if we only get two dry years together we take the mean of two dry years.

6527. For what period have you storage?—If we provide storage, say for 120 days, and we start with our reservoirs full, that is just one-third of the year, and if we calculate on obtaining 36 inches in the year, the water in store would be equal to 12 inches of rain. Therefore we can add 12 inches throughout the whole year to the minimum year, or if it goes on for two years we can add 6 inches, or if it goes on for three years we can add 4 inches.

6528. Should you not take the minimum year *plus* that 12 inches?—No, there would be no use in reservoirs if reservoirs are not to help out periods of drought. You will understand that if we have storage which is equal to 120 days' supply that is equal to one-third of the year. If we calculate with reference to collecting 36 inches that we shall have 12 inches store, and if you come to a year which is 12 inches below what we can calculate upon, our store will just meet that. If it has to last us two years there are 6 inches, and if there are three consecutive dry years, and you calculate upon your reservoir lasting three years, you have 4 inches in store to go to help out deficient years.

6529. You say you calculate upon a storage equal to 120 days?—Yes, that certainly should be the quantity, or 140 days for a smaller quantity.

6530. That 120 days' storage being equal to a rainfall of 12 inches?—Yes, over the year.

6531. Is not that the quantity which you have to add on to a minimum year?—It would be, but I am lowering it on purpose. I have taken only 36 when I might have taken 48. Supposing I had taken 36 inches, and 36 was the mean of two dry years, and in one year there happened to be only 24 inches collected, I have 12 inches in store. I should get my 36 inches discharged, and if I should be empty at the end of the year I should start the next year with an empty reservoir. If I have two years to provide for, and calculate upon the reservoir working for two years, and I have 36 inches, and that is all the rain I can get on the average, and I then have a fall of rain of 30 inches only, I could discharge that 30 inches and 6 inches out of my 12 inches of store, and make it up to the 36 inches, and I should then start with the reservoir just half full, with 6 inches in store towards another dry year,

6532. Then do I understand you rightly that the total amount of your storage would not exceed 12 inches of rainfall?—Yes; the total amount of my storage is just 12 inches in depth over the whole surface.

6533. Supposing we were at the beginning of the driest year, that is the total surplus which you could carry over from the previous year to make up the deficient supply of the driest year?—That is so. I should never be short, inasmuch as I have 48 inches upon the average—certainly more than 40 inches after deducting for loss in the driest year. I should never exhaust my store. I should always have water in store.

6534. It would seem, then, that the surplus quantity of 12 inches must be added to the driest year that could possibly occur?—Yes; but the driest year that may possibly occur in that district would exceed 40 inches after making deductions; 60 inches upon the mean of three dry years might be said to represent perhaps 52 or 53 inches in an extreme year, or something like that. Deduct 12 inches from that, and you have 40 or 41 inches, and as you only calculate upon discharging 36 inches, you have four or five inches to the good on that year, or if you discharge the whole 40 or 41 inches, supposing you have none running to waste by floods, you have just equal to the demand, and it leaves you with your reservoir full at the end of the year.

6535. It all rests, does it not, upon what may be the minimum rainfall?—Yes. I think I have stated sufficient to show that the minimum rainfall is not half of the average, but perhaps two-thirds of the average. The minimum rainfall of 75, or in round numbers 74 inches, would be certainly over 50 inches. I have had a table just handed to me of the rainfall in the Loch Katrine district, and there is one case in which the rain has been gauged for 15 years, during which time there were two very dry years and some wet ones, and there I find the mean rainfall was 59 inches, and the minimum was in 1855 39 inches; that is just two-thirds; if it was 40 inches and 60 inches it would be exactly two-thirds. I will take another year, a low country gauge for the same number of years. The mean rainfall was nearly 54, and the minimum rainfall was nearly 35; that is not two-thirds. Then I will take the rain gauge at the head of the Duchray valley, which has a very large rainfall, amounting to 114 and 117 in some years, and some years very much less; there the mean rainfall was 90·6 and the minimum rainfall in 15 years was 67·2, that is more than two-thirds. In 22 years in the Cumberland district (this is from Mr. Symons's tables) the mean rainfall was 58·53 and the minimum in 1855, which was also the minimum in the table which I have given you, was 37·40, that is rather more than two-thirds. There seems to be no case in which it falls lower than two-thirds, and hardly a case in which it does fall to two-thirds; so that the minimum rainfall here may be said to be 50 inches out of 74 inches, which is the mean rainfall.

6536. Those two districts are districts in which rain-gauges have been carried on in one case 15 years, and in the other 22 years. How long a period have your experiments extended over in the Welsh district?—Taking the Rhayader gauge 10 years.

7537. All those districts are districts of extreme rainfall, but do you not suppose that you would be liable in the Welsh district to as great extremes as occur in the Scotch and in the Cumberland districts?—Just so; and the extreme seems to be as nearly as possible in the Cumberland district two-thirds, and in the Loch Katrine district two-thirds also; that is to say, the minimum rainfall is two-thirds of the mean rainfall.

6538. Are there not, in both those districts, instances in which the rainfall fell below 40 inches in particularly dry years?—No, that was at particular gauges (it was not the mean of all the gauges), and those happened to be low-country gauges; the mean is two-thirds. If you take Seathwaite the driest year was 88 inches. You cannot determine what their particular amount would be, but you can determine the proportion which a minimum year bears to an average year. If the average rainfall is 75, and you take two-thirds, that would be 50; if the average rainfall be 45 two-thirds would be 30; if it be 90 two-thirds would be 60. If you take the Glasgow table, which represents the rainfall of the Loch Katrine district, and the tables of the rain at the places which Mr. Symons took for his

standard returns, in both those cases the minimum is as nearly as possible two-thirds of the mean rainfall.

6539. Is not that an estimated quantity?—No, not an estimated quantity; it is the actual quantity. In the Cumberland district it bears the proportion of 37·40 to 58·53, and in the Loch Katrine case it bears the proportion of 67·2 to 90·6; and in another case which I gave you it bears the proportion of 39 to 59. That is almost exactly two-thirds. *J. F. Bateman, Esq.* 4 March 1868.

The witness withdrew.

Adjourned to to-morrow at 12 o'clock.

Thursday, 5th March 1868.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND, K.G., IN THE CHAIR.

Sir JOHN THWAITES.	THOMAS ELLIOT HARRISON, Esq.
Colonel HARNESS, C.B.	JOSEPH PRESTWICH, Esq.

JOHN FREDERIC BATEMAN, Esq., further examined. *J. F. Bateman, Esq.* 5 March 1868.

6540. (*Sir J. Thwaites.*) Before proceeding to the next subject, permit me to ask you a question with respect to the gauging of the Thames at the point indicated on the sections which you have handed in. You have adopted a very ingenious and certainly a very simple mode of ascertaining the mean velocity of the stream, and probably something of the same kind was used by Mr. Foster in 1851, though not with the same accuracy as now; what I want to know is, whether in adopting this principle of gauging it is the recognized formula used by engineers, because they are generally careful in thoroughly testing any new principle in its application, especially to large streams. You took, I think, seven sections?—Yes.

6541. And the velocity of the stream was ascertained from one section to the other?—Yes, the mean of all the observations upon the sectional area to which those particular observations applied.

6542. Did you apply your floats to the sides of the stream as well as the centre?—Yes.

6543. I understand that the principle which you adopted was to submerge a ball within such a distance of the bottom as not to come in contact with any substance, and to submerge another ball to the extent, probably, of seven-eighths of its bulk, near the surface?—Yes.

6544. And those two balls were tied together?—Yes.

6545. And the friction at the bottom of the river impeding the current of course kept a check upon the upper ball?—Yes.

6546. And by that means you obtain what you consider to be a correct mean velocity of the stream?—Yes.

6547. After those gaugings were made did you test on the same sections the formulæ generally used by engineers to test the correctness of this principle?—I do not think that was done. This mode of ascertaining the mean velocity is much older than I am. I have adopted it for the last 25 or 30 years, and I have every reason to believe by other experiments made expressly for the purpose of determining what formulæ we can found upon, and what we cannot, that it represents, as nearly as we can determine it, the results of the most careful formulæ deduced by other people. But you will see that except in some such way the velocity at the bottom can never be ascertained.

6548. I only want to know the fact whether you tested it by any other formulæ on the same ground?—Not on the same ground, but I have tested that mode of gauging frequently in other places where I have had the means of making every possible observation. When I laid out the Manchester waterworks, I constructed the works in many parts with special reference to taking such observations as would determine a great many points which were somewhat in doubt, and I then tested all the calculations of almost everybody, upon the watercourses in the Manchester waterworks, where we had every facility for doing it.

6549. And what has been the per-centage of error, as compared with the usual formulæ?—One has to use our formulæ with some amount of caution, because the formulæ have been determined from experiments made under certain conditions, and our experience and practice enable us to determine the conditions which are either more favourable or less favourable to the truth of the formulæ. I will give, for instance, the case of a common formula for calculating the quantity of water discharged over a weir. The ordinary formula is to extract the square root of the depth of the water in feet flowing over the weir, and take two-thirds of that and multiply it by 5·1. Through an aperture which is wholly submerged you multiply the area by the depth upon the centre of the aperture, and multiply the square root of that by 5·1, but according to the character of the opening the proper co-efficient will vary from 5 or 5·1 to nearly 8. In the gauging observations made on the Manchester waterworks for the express purpose of ascertaining how that was, a certain gauge basin was constructed, and in that I made three apertures 6 feet long and 6 inches deep, all of exactly the same dimensions and under the same head. Then I received the water discharged through the aperture into a large vessel made expressly for the purpose, a square tank, so as to determine the exact quantity of water flowing into the vessel in a given time. Then I reduced the proper formulæ from the quantity of water which was received and therefore discharged through those various openings, and the co-efficient of discharge varied according to the three classes of openings (I will explain this directly) from 5·6 to 7·76. A velocity of 8·04 is the full velocity which can be acquired by a falling body falling 1 foot, and through one particular opening the discharge was nearly equal to the velocity due to the whole depth through which the body would have fallen. (*The witness described the experiment upon a drawing.*) In all those cases one has to regulate very much the application of the formulæ according to our knowledge and experience.

6550. In dealing with large streams no doubt the difficulty is increased?—Yes, and that was the reason especially which made me reject all formulæ and ascertain upon the spot what was the actual velocity, and I could not ascertain what was the actual velocity in a more perfect way I believe than the way which I adopted. Therefore that is independent of all formulæ, and if the formulæ do not agree with it the formulæ are incorrect.

6551. I am induced to put the question to you, because Mr. Simpson having made a very careful gauging of the velocity of the stream, or a very accurate section having been made by him from time to time, the serious difference between you and Mr. Simpson upon that point gave rise to some anxiety in one's mind as to whether Mr. Simpson was wrong or you were wrong, and whether it might be due to the mode of gauging on one side or the other?—I do not pretend to say that Mr. Simpson is wrong, but the

J. F. Bateman, Esq.

4 March 1868.

actual results are worked out there. I may observe that I was wrong in stating as I did yesterday that 1865 was the driest year in the Lea and the Thames. It appears that 1864 was the driest year, but it was the excessive drought to which we were subjected in the north of England which led me to ascertain what quantity of water was in the Thames in that year. I believe 1864 was really a severer year, and I have before me the particulars, not so much of the Thames as of the river Lea.

6552. Would not the severity of the drought of 1864 manifest itself in the discharge of 1865?—Most likely it would, but I see that the quantity of rain which fell in the two or three months immediately preceding September 1865 was very considerable. Of course in a chalk district like the upper part of the Thames basin the water is a long time percolating and discharging, and the rain of the autumn influences the spring of the next year probably.

6553. (*Colonel Harness.*) The plan which you adopted gave you, did it not, six whole values of discharge, there being six intervals?—Yes.

6554. Do you remember the difference between the greatest and the least?—I do not. I may mention that the gentleman who took these gaugings in the Thames, who now is in America, and the young gentleman who assisted him in this operation, and who is now in Glasgow, came to this operation fresh from having gauged the river Shannon at various places for the purpose of an inquiry for government, and they were thoroughly up to everything that was required.

6555. (*Chairman.*) Taking you back for a moment to the district which you were upon yesterday, namely, Manchester, Blackburn, Burnley, and various other places as to which you gave us the amount of water which they got and their gathering grounds, would it be possible before we leave that part of the subject for you to give the Commission any information with regard to Sheffield, which is not very far from that district?—Sheffield has recently acquired an enormous amount of gathering ground. By an Act of Parliament passed only last session it has got command over an extravagant amount of ground for the supply of Sheffield, namely, 36,000 acres, which is as nearly as possible twice the acreage which Manchester has acquired. The rain is not quite so much on the east as it is on the west; but if you take it at 24 inches, which is about the available produce in the Sheffield district, or perhaps rather more in the district which they have last gone to, it will give 54,000,000 gallons of water a day, and if they give one-third of that as compensation they will still have something like 40,000,000 gallons a day at the command of Sheffield and the surrounding district.

6556. Are they constructing any very large works?—They are constructing reservoirs. In the valley in which the unfortunate Bradfield reservoir gave way, they are constructing two reservoirs, one immediately above and one higher up, and in the adjoining valley called the Agden valley they are constructing a very large one. The new reservoirs which they obtained the Act of Parliament for last year are eight or nine in number, and their embankments vary from 66 to 94 feet in height.

6557. Are you carrying out those works?—No, Mr. Hawkesley is the engineer to them. I originally chalked out the first great extension which they made, but the works were carried out by Mr. Leather and Mr. Gunson, the resident engineer. I am to some extent responsible for the general arrangements of the scheme, but not for the sites of the reservoirs. When the embankment burst many gentlemen were called in, amongst others Mr. Harrison, to report upon the cause of the destruction of that embankment, and after the Act of Parliament was passed Mr. Hawkesley was appointed engineer to the company, and to the new embankments of last session. There are seven new reservoirs, and the heights of the embankments vary from 66 feet to rather more than 94 feet, 66, 74¾, 80½, 82, 90½, 94 feet 2 inches, and 94 feet 4 inches.

6558. Having as you have stated this very large gathering ground, and an amount of water far in excess of what in your opinion they can require, would they be able to supply with water the towns that are below them on the same line of country?—They would, and I have no doubt that that will be the ultimate result, because they cannot use all the water that they have acquired, and they will supply the distant towns exactly in the same way as Manchester is now supplying places far distant from the hills.

6559. Will you put in some population returns about which you were asked yesterday?—I was asked yesterday for some particulars respecting the population in Lancashire. I find that the total population of the county of Lancaster in 1861 was 2,429,440, and that of the towns of which I gave a list yesterday amounts to about a million and a half. I find that in the larger places, towns exceeding 3,000 inhabitants, up to large places like Liverpool and Manchester, nearly all of which are supplied with water, there are 1,648,000 persons in round numbers, and the populous villages, of which I have a list, that is to say parishes and places varying from about 2,000 to 16,000, put together come up to a population of 187,000 and that makes a total of 1,834,000 out of 2,429,440, the remainder being rural population in scattered places. And in this table I have marked with a cross all those places, which, as I happen to know of my own knowledge, are supplied with water by means of waterworks either in the hands of companies or of the local authorities. There are some places which I have every reason to believe are supplied, but I cannot positively say so, which I have marked with a point representing a doubt, and amongst those there are other places which are supplied in whole or in part from wells in the new red sandstone, which I have marked with a circle; so that this table will show at a glance the condition, so far as I am able to state it to the Commission, of the water supply of the principal places in the county of Lancaster. You will find that there are very few places in the table to which I have not attached a mark signifying my own knowledge of their means of supply. Other places there may be, but I have not the means of stating whether there are or are not, positively. I beg leave to hand in the following table:—

COUNTY OF LANCASTER. Population taken from the Census Tables of 1861.

The places marked in the accompanying table with a * are now supplied with water by means of waterworks in the hands of companies or local authorities.

Those marked ? are believed to be so.

Those marked thus o are either wholly or partially supplied from wells in the new red sandstone.

POPULATION of City, Borough, or Towns in the County of Lancaster, from the Census Tables of 1861.

Total Population of the County of Lancaster in 1861, 2,429,440.

Name of Place.	Population.	Name of Place.	Population.
*Accrington	13,872	*Middleton	9,876
*Ashton-under-Lyne	34,886	Much Woolton	3,296
*Atherton	2,692	New Church	3,115
*Bacup	10,935	Newton in Mackerfield	5,909
*Blackburn	63,126	*Oldham	72,333
*Blackpool	3,506	o*Ormskirk	6,426
*Bolton	70,395	*Padiham	5,675
*Burnley	28,700	o*Prescot	6,066
*Bury	37,563	*Preston	82,985
*Chorley	15,013	*Rochdale	38,114
*Church	3,000	o*St. Helens	18,396
?Clitheroe	7,000	o*Southport	8,940
*Colne	6,315	*Stalybridge (part)	15,000
Dalton	2,812	Todmorden	5,029
*Over Darwen	14,312	*Tyldesley	3,950
*Droylsden	5,980	*Ulverston	6,630
*Farnworth	8,720	*Warrington	26,451
*Fleetwood	3,834	oWidnes	4,803
Great Harwood	3,294	*Wigan	37,656
*Haslingden	6,929	*Bradford	3,523
*Heywood	12,824	*Lower Darwen	3,301
Hindley	8,477		
*Kirkham	3,380		1,647,792
*Lancaster	14,437	Populous villages or places on page No. 2	187,069
*Leigh	10,621		
o*Liverpool	443,938		
*Lytham	2,556	Total population in boroughs, towns, or places	1,834,861
*Manchester 338,722			
*Salford 102,449			
	441,171		

COUNTY OF LANCASTER.

Population of Villages or Places not included in the foregoing Table.

Name of Place.	Population.	Name of Place.	Population.
Livesey	3,581	*Royton	7,493
?Walton-in-le-dale	7,383	*Heaton Norris, part of Stockport.	16,333
*Witton	3,292		
Blackrod	2,911	*Gorton	9,897
*Darcey Lever 2,071		*Failsworth	5,113
*Little Lever 3,890		*Crumpstall	4,285
	5,961	?Blackley	4,112
Harwood	2,055	?Levenshulme	2,095
*Sharples	3,294	*Moss Side	2,995
*Tonge with Haulgh	3,539	*Openshaw	8,623
Turton	4,513	*Rusholme	5,380
?Garston	4,720	*Stretford	8,757
*Wavertree	5,392	*Withington	2,712
Halliwell	5,392	*Chadderton	7,486
Horwich	3,471	*Ratcliffe	8,838
Little Hulton	3,390	?Crosby, Great	3,794
Kearsley	5,003	Shaw	3,618
*Newton	14,907		
?Crompton	7,032		187,069

6560. Will you now proceed with your evidence upon the subject of the reservoirs?—I stated in answer to a question from Mr. Harrison in my former examination, that the surveys were made from actual observation, that is to say, the reservoirs and embankments were computed from actual observation, and they were so by the aneroid barometer principally. A doubt was expressed as to whether the reservoirs were so large as I had stated them, and, therefore, to determine that point, and entirely set it at rest, I have had every reservoir accurately surveyed and sections of the embankments taken, and actual surveys made since then. I am rather glad to have an opportunity of correcting my evidence upon that point, because not only in the quantity of earthwork in the embankments, but in the capacity of the reservoirs I find that I was very much within the truth as to the capacity of the reservoirs, and over the truth as to the cubical contents of the embankments. I will hand in a table showing the total capacity of the reservoirs and other particulars upon an accurate re-survey. The mean of available rainfall, as I showed yesterday, of three consecutive dry years for the whole district was 50 inches; and assuming 120 days of drought, the reservoirs, and dry weather volume of the streams would afford a supply of 379,000,000 gallons daily to streams and the city, and that if measured by that number of days and the springs taken into account represents 46·6 inches obtained from the ground. That is exclusive of the district which is marked upon the map behind you with green streaks, which is a large portion of the river Severn proper, and which Mr. Pole recommended should be included in the scheme, which I had previously rejected on account of there being lead workings at the time I examined the ground in the first instance. Those lead workings are discontinued, and that district therefore might be taken into account. But if, excluding that area, and confining ourselves entirely to the area which I had the honour of laying before the Commission on the former occasion, we supply this quantity of water, which is equivalent to 250,000,000 gallons a day to the metropolis, it would be equal to a collection of 46⅔ inches from the ground.

6561. (*Sir J. Thwaites.*) When you make use of the term "collected," do I rightly understand you to mean that 46 inches is the net result of that which is available for supply?—It may or may not be. If we were to discharge from those reservoirs 220,000,000 gallons a day, and we assume that the streams throughout on the average of the whole of those 120 days gave 30,000,000 gallons a day, that would be a total discharge of 250,000,000 gallons to the metropolis, besides the quantity of water which would be discharged to the river, which would be about 90,000,000 gallons a day more. If all that water was discharged, it would be equal to a collection of water over the whole of that surface of 46⅔ inches. If we measured the discharge by 140 days, so as to make the reservoirs last out 140 days instead of 120 days, and assumed the average volume of the streams during that time to be 25,000,000 gallons, that would be equivalent to a collection and discharge of 40½ inches of water. I showed yesterday that you might reasonably expect 50 inches as the available supply on the average of two or three consecutive dry years. Those are all the particulars which I have to give with respect to the reservoirs, and I may state generally, before I hand them in, that the gross capacity of the reservoirs, as I stated them on the former occasion, was in round numbers 5,709,000,000 cubic feet; the re-survey brings up the quantity to 6,709,000,000 cubic feet. Therefore I stated them 20 per cent. less than the proper quantity. You will find the sections of all the reservoirs, the Trefeglws reservoir and the rest, one after the other. The table contains every calculation with regard to them. (*The witness delivered in the following table.*)

J. F. Bateman, Esq.

5 March 1868.

PARTICULARS OF RESERVOIRS proposed to be constructed in the Welsh Scheme.

District.	Drainage area.	Height of embankment.	Area of surface of reservoirs.	Total capacity.	
				Cubic feet.	Cubic feet per acre of drainage area.
	Acres.	Feet.	Acres.		
Vyrnwy and Banw District:					
Llanwddyn Reservoir.	22,352	76	1,165	1,490,80 330	66,660
Can office Reservoir.	15,044	80	680	767,171,800	45,526
Rhyd e Gro Reservoir.	16,477	80	600	974,63[illegible],900	
Nant e Eira Reservoir.	12,507	80	200	261,360,000	
Total	66,380	—	2,645	3,493,977,030	52,646
Severn proper District:					
Clwyedog Reservoir.	13,500	70	300	203,056,522	50,000
Dulas Reservoirs?	15,139	—	300	217,800,000	
Trefeglws Reservoir.	35,553	76	1,600	2,794,717,000	
Total	64,192	—	2,200	3,215,573,522	50,000
Total of both districts.	130,572	—	4,845	6,709,550,552	51,390

	Reservoirs as laid out will supply			
	For 120 days.		For 140 days.	
	Compensation to streams at 9 inches of rain.	To the city.	Compensation to streams at 9 inches of rain.	To the city.
	Gallons.	Gallons.	Gallons.	Gallons.
Vyrnwy and Banw District.	37,118,487	144,817,383	37,118,487	118,826,544
Severn proper District.	35,910,144	131,567,644	35,910,144	107,642,244
Totals	73,028,631	276,385,027	73,028,631	226,468,788
Streams during these periods will yield about ½ a cubic foot per second from every 1,000 acres—say from 130,572 acres	—	30,000,000	—	25,000,000
Totals	73,028,631	306,385,027	73,028,631	256,468,788

Mean available rainfall of three consecutive dry years for the whole district	50 inches.
Assuming 120 days drought, reservoirs and dry weather flow of streams will afford a supply of 379,413,658 gallons daily to streams and city, being equal to an available annual rainfall from the whole district of	46·621 ins.
Assuming 140 days drought, reservoirs and dry weather flow of streams will afford a supply of 329,497,414 gallons daily to the streams and city, being equal to an available annual rainfall from the whole district of	40·595 ins.

In the plans and sections which I will also hand in the reservoirs themselves look very small, but they are from the same scale as the Ordnance Survey. The sections are upon a larger scale. (*The witness delivered in the same. Vide Appendices.*)

6562. (*Chairman.*) Have you anything more which

J. F. Bateman, Esq.

5 March 1868.

you wish to state with regard to the reservoirs, or have you done with that part of the subject?—I do not think that I have anything else to state, except that the embankments vary from 70 to 80 feet, the highest. There are three reservoirs at 80 feet, one at 70, and two at 76, and I may state that in the Dulas valley, which is the one through which the railway goes, I have not estimated actually for the reservoirs which have been laid out, but I have taken an estimate of the other reservoirs at the proper quantity for that valley on the scale of the other reservoirs, assuming that I can find other sites for reservoirs as good elsewhere, and not the lowest price but the highest price.

6563. (*Sir J. Thwaites.*) What is the internal slope of the 80 feet reservoir?—Three to one. The estimate includes every expense. The situations are remarkably good; it is impossible to find better ground anywhere in the world. The materials of which they will be constructed are also equally good, and the estimate includes a considerable amount of what is called beaching on the slopes where the banks are clay, for the purpose of preventing the discolouration of the water. I do not think I can go further into that matter than I have done.

6564. (*Chairman.*) Have you, since you gave evidence before, looked into and revised the estimate which you then gave?—Yes, I have gone carefully over everything, and the estimate, including the arrangements for connecting with the existing water companies, I have prepared in great detail. I thought it better to give it in detail for the purpose of examination. I have prepared it for a supply of 230,000,000 gallons. The total supply which the works are laid out with reference to at the various stages is 130,000,000 gallons, 170,000,000 gallons, 200,000,000 gallons, and 230,000,000 gallons, and I have also estimated what the additional cost would be if it were laid out with a view to ultimately obtaining 300,000,000 gallons a day from this district. The whole difference between the estimates which I laid before you on a previous occasion and the present estimates is 140,000*l.* more in the present one. I had not then gone anything nearly so carefully into the mode of connecting with the existing companies as I have since done, and when the whole quantity is brought it will be about 1,000,000*l.* more than it was previously estimated, owing to the extra cost which appears to attend the connection with the existing companies. Here are the particulars of the estimate in gross, and the particulars of the watercourses.

6565. (*Sir J. Thwaites.*) What are the particulars in gross?—The gross estimate, exclusive of interest on money, current expenses, superintendence, and engineering, for obtaining 230,000,000 gallons, and exclusive of the cost of connecting with the existing companies, is 9,317,205*l.* I have added 10,000,000 gallons to the former estimate, as I find that everything will carry 10,000,000 gallons more. I measured the capacities of the works by the size of the reservoirs. The reservoirs were larger than I had anticipated, and I have added 10,000,000 gallons in consequence, and they now will give 230,000,000 gallons against 220,000,000 gallons as before estimated. I have measured the capacities of the district, not by the water to be collected, but by the size of the reservoirs, for 230,000,000 gallons, and distributing it to the existing centres of supply in London, and including every expense attending the connexion with the works of the existing companies in the re-arrangement of pipes and whatever will be required, it comes to 10,317,205*l.*

6566. Your previous estimate for the smaller quantity was 10,850,000*l.*, was it not?—Yes, but there has to be added a sum for interest of money during the construction of the works, and for engineering and superintendence, and then if you add about the same amount that I allowed before, which was 1,140,000*l.* or something of that sort, or rather more, perhaps, say about 1,500,000*l.*, which would be something like it, that would make it 11,800,000*l.*, including all the current expenses of superintendence, engineering, legal expenses, Acts of Parliament, and other things.

6567. (*Col. Harness.*) Does that include the supply reservoir near London?—Yes, that includes the supply reservoir near London, and all the pipes from thence to connect with the existing companies. Then if you take it at 130,000,000 gallons only, which is the first instalment, the total cost of that in outlay will be in round numbers 7,600,000*l.* That includes reservoirs near Edgware or near Stanmore. They are about equally distant from each place, and it includes connexions with the existing works of distribution. From that I deduct the value of the property which may be disposed of supposing the new water were introduced. There are various chief rents which in themselves are of a very considerable value, especially those belonging to the New River Company, and the land and engines, pipes, and other things, and a low estimate upon these I think is 1,000,000*l.* Therefore I deduct 1,000,000*l.* for those things which would be set at liberty, so that 6,602,000*l.*, exclusive of interest of money and so on, is the net cost of obtaining 130,000,000 gallons, and of connecting the supply with the existing distribution arrangements in the metropolis. I will show why I take 130,000,000 gallons. That appears to be something like the quantity which will be required by the time the works can be executed, and by the time the water would be introduced. Then I go on with an estimate for 40,000,000 gallons more, making 170,000,000 gallons altogether. That I apprehend, from the evidence which has been given, is the quantity which the witnesses calculate upon obtaining from the Thames and the Lea together, without the construction of reservoirs upon the Thames or upon the Lea. The total cost of obtaining that quantity will be in round numbers 8,500,000*l.*, that is also exclusive of interest on money, superintendence, and other things. And for the third instalment of an extra 30,000,000, which brings it up to 200,000,000 gallons, which is a good convenient round figure, the estimate is about 8,750,000*l.* And for the fourth instalment, which brings it up to 230,000,000 gallons, which is about the scale of the works as laid out, the amount is brought up to 9,300,000*l.* I have omitted in this estimate the interest on the money and other expenses of that nature, because I have to compare the amount which I have given with the cost of obtaining the same quantities of water from the Thames and the Lea, in order that you may see exactly, as nearly as I can estimate it, the comparative cost of obtaining the water from both sources; and as the expense is in some cases rather more, and in some cases rather less, the interest of money you will be able to determine without reference to the actual cost of the works to be constructed. This view supposes that the works in either case had to be completed before water was supplied. I will now hand in a summary of the estimated outlay for obtaining and distributing the supply from Wales, upon which I have just given evidence.

WELSH SCHEME.—SUMMARY of ESTIMATED OUTLAY for obtaining the supply from Wales and distributing same to existing centres of supply:—

1st instalment of 130,000,000 gallons daily:		
Reservoirs and works for collecting and storing water in the Vyrnwy and Banw district, including land and contingencies - - -	£489,882	
Branch aqueduct from river Banw to Marten Mere, including land and contingencies - - -	599,137	
		£1,089,019
Main aqueduct from Marten Mere to service reservoirs near Edgware. Syphon pipes capable of discharging 130,000,000 gallons daily		5,453,359
Amount carried forward -		£6,542,378

Amount brought forward - - - -		£6,542,378
Service reservoirs near Edgware, and distribution of water to the various districts. - -		1,059,810
Total cost of obtaining first instalment of 130,000,000 gallons daily - - -		7,602,188
Deduct value of property which may be disposed of as soon as supply by gravitation is introduced - - - - - - -		1,000,000
		£6,602,188
2nd instalment of 40,000,000 gallons additional:		
Reservoirs and works for collecting and storing water in the river Severn proper district, including land and contingencies, £570,291		
Branch aqueduct to Marten Mere, including land and contingencies 492,117		
	1,062,408	
Additional syphons on main aqueduct from Marten Mere to Edgware - - - - - -	266,650	
Additional service reservoir near Edgware, and piping and other works for distribution of water to the various districts - -	557,551	
		1,886,609
Total cost for obtaining a supply of 170,000,000 gallons daily - - -		£8,488,797
3rd instalment of 30,000,000 gallons additional		
Additional syphons on main aqueduct from Marten Mere to Edgware - - - - - -	£133,324	
Additional mains and works for distribution of water - -	117,535	
		250,859
Total cost of obtaining a supply of 200,000,000 gallons daily - - -		£8,739,656
4th instalment of 30,000,000 gallons additional.		
Additional syphons on main aqueduct from Marten Mere to Edgware - - - - - -	£133,324	
Additional service reservoir near Edgware, and for distribution of water - - - - - -	444,225	
		577,549
Total cost of obtaining a supply of 230,000,000 gallons daily - - -		£9,317,205

These estimates are exclusive of interest of money and expenses during construction.

I will also hand in a statement of the particulars, together with estimates for the four instalments upon which I have calculated, and also a summary of the whole (*see Appendix M* (1)).

6568. (*Sir J. Thwaites.*) Is any other item excluded besides that of interest?—Nothing else is excluded but interest and current expenses. If you will allow me I will add to each of those items, as nearly as I can estimate it, the interest of money and the expenditure which will be required in superintendence and so on during construction. I will now lay before the Commission a map showing a portion of the line of aqueduct from Wales to London (*delivering same in*). This map shows the line of tunnel terminating at the service reservoirs near Stanmore, about a mile north of Edgware, and the tunnel terminates at a level of about 270 feet above ordnance datum. I am astonished that anything like sites for such reservoirs can be found so near the city of London. There are more than 500 acres in the two reservoirs which are colored red. They do not interfere with a road nor do they destroy a house, nor is there a house which overlooks them except two small villas, and you may make almost as many reservoirs as you like under similar circumstances underneath the hills there. The two which are marked red on the map I have specially surveyed, and I can give their actual contents and cost. The third, marked in red outline, has not been accurately surveyed. The new Midland Railway now runs right up the valley and that adds very much to the cost, otherwise those two reservoirs would have been joined by a short embankment. The embankment of the Midland Railway might have been used for the reservoir, but it happens to be some 16 feet too low, and therefore we are obliged to make the embankment alongside the railway and to terminate at a higher point. The greatest height of embankment is about 50 feet. (*The witness described the position of the reservoirs, &c. upon the map, see Appendix A N* (1)). As to the capacity of the reservoirs, you will observe that there is a section of the one embankment, and there is a section of the other embankment, and one cross section of each reservoir (*see Appendix A N* (2)). The reservoirs themselves will be from 35 to 40 feet deep.

J. F. Bateman, Esq.

5 March 1868.

6569. What is the height above high water at the mean point of your discharge?—It is about 270 feet above ordnance datum, and 257½ above Trinity high-water mark. This embankment at its deepest part, which is just in the valley, is 66 feet, and the height of the other is 68 feet at the lowest part. It runs parallel with the Midland about 30 feet, and I think it is 15 or 16 feet above the Midland Railway at its lowest point. The whole of this work would be in London clay, and there is not an arable field, there are a large number of green pasture fields rather swampy. Above the London clay we get abundance of gravel for beaching the whole surface, so as to prevent any disturbance of the side by the agitation of the water by the wind. We excavate nothing except what is necessary for the formation of the bank, and that will give us, by proper arrangement, a depth, except in the slopes, of 20 feet at the shallowest place; here is another sheet (*producing the same*), and you will see that there is not a road nor a house upon the site.

6570. (*Mr. Harrison.*) With regard to these reservoirs, and with regard to those in Wales, you think you have obtained sufficient information from actual survey to enable you to make as correct an estimate as you would make if you were going to Parliament for an Act?—Just the same. Those two reservoirs contain 21 days' supply upon 130,000,000 gallons a day, and you may make as many more almost as you like in the same way; by tunnelling through another part of the ridge and coming to the head of an adjacent valley, you may repeat the reservoirs there. That answers very much the question which was asked before as to the danger of depending upon one source only for the supply of London. You may construct reservoirs there which will contain I should think something like six weeks or two months supply, and you may defend them if you choose by fortifications on the top of the hill; they would not be half so liable to disturbance as the pumping stations at Hampton or Thames Ditton, and you have from each four or five different pipes and means of communication which could hardly be discovered even by a hostile army, and you might get a supply of water which would last out a siege of two months, or by eking it out, of three or four months, independently of any external supply whatever. Those reservoirs are nearer to London and less liable to injury and are more defensible than the existing means of obtaining a supply. The capacity of the western reservoir is 1,230,000,000 gallons, and the capacity of the eastern reservoir is 1,549,000,000 gallons, in round numbers. In consequence of the Midland Railway the amount of earthwork has been very much increased. The total amount of earthwork in the two embankments is now 1,687,000 cubic yards, all of which will be excavated out of the reservoir and below high-water mark. That amount has been added to by the Midland Railway going up so unfortunately there, are perhaps that will increase it 300,000 or 400,000 cubic yards.

This map also shows the lines of communication with the existing waterworks companies. The upper red line starts from the eastern reservoir and runs in a south-easterly direction to the point at which it bifurcates into two branches. That aqueduct is exactly the same size as the Loch Katrine aqueduct and is laid out for the conveyance of about 60,000,000 gallons of water per day, with a fall of 14 inches in a mile. It is a covered aqueduct the whole way exactly on

J. F. Bateman, Esq.

5 March 1868.

the scale of the Loch Katrine aqueduct, and it brings all that water to a place called Crouch End, immediately above the north and east of London, at an elevation of 240 feet, so that you have the water brought immediately above London at an elevation of 240 feet. From there commence the arrangements for distributing the water to the east end of London. Then you have another pipe taken from either or both reservoirs, which will take the water to the Campden Hill reservoir of the Grand Junction and West Middlesex Water Companies, another pipe which will take it on to the Putney Heath reservoir of the Chelsea Waterworks, another pipe which will take it on to the Streatham Hill reservoir of the Lambeth Waterworks, and another pipe which will take it on to Blackheath, to the Kent Water district.

But before going into all these details, I must endeavour to explain to you the manner in which the town is now supplied. There are some plans (*producing the same*) which were prepared by Mr. Ranger in a report made by him to the Hon. William Cowper some years ago, showing the manner in which the town was divided into districts and the sources of supply.

There are three pumping stations at Hampton on the river Thames, the Grand Junction, the West Middlesex, and the Southwark and Vauxhall. The Grand Junction and the West Middlesex Companies by two partly different routes convey the water to Campden Hill, where they have service reservoirs. There the Grand Junction Company has erected a stand pipe for the purpose of supplying the higher districts, while the lower districts are supplied from the level of the Campden Hill reservoir; one reservoir is 124 feet and the other is 132 feet above the level of high water. I do not remember at this moment which belongs to the Grand Junction and which to the West Middlesex Company; the lower level reservoir I think belongs to the Grand Junction Company, and the higher level reservoir to the West Middlesex Company. The West Middlesex Company supply the lower portions of their district from that reservoir, and they pump the water for the higher districts to a reservoir 190 feet above the ordnance datum at Barrow Hill, and they have recently erected a reservoir at a still higher level. The Southwark and Vauxhall Company take their water from the same spot, and take it by a different route to Battersea on the south of the river Thames. They have no reservoirs at all, they pump the water with the aid of stand pipes for the purpose of reducing the friction, and they deliver the water to their district by pumping it up the stand pipe, and so get a pressure which supplies the district. Part of that is delivered at 180 and a small portion of it, for a very high point, at 350. I think that is the pressure upon their pumps. The Chelsea and the Lambeth Companies, which are the two remaining companies which draw their water from the Thames, take their water from Thames Ditton. The Chelsea Company by a much shorter route than any of the other companies take it to a reservoir at Putney Heath at 172 feet above the level of ordnance datum, and from there by an aqueduct across the river at Putney they supply the whole of their district. The Lambeth Company pump into two reservoirs at different heights. The one which I shall specially allude to is at Streatham, which is 197 feet high, which is high enough for the supply of nearly the whole of their districts; but there are high points at Norwood, the Crystal Palace, and places of that sort, which require a higher elevation still, and they pump into another reservoir for that purpose.

The Kent Company pump their water into reservoirs near Blackheath; there is one reservoir near Shooter's Hill, and one reservoir in Greenwich Park. I am not quite sure of their arrangements, but they supply I believe from those reservoirs.

Then there come the East London and the New River companies. The East London Company take their water from the river Lea now at two points which are almost the lowest, and which are in the very heart of the district which they have to supply, and therefore they have not the difficulty and expense of overcoming the friction. Instead of having to convey the water before they get to their field of distribution 14 or 15 or 16 miles, as all companies, except the Chelsea Company, have to do who draw water from the Thames, they are at once in the heart of the district, and save at least 150 feet of pumping head in consequence of that advantage. The New River Company also come by gravitation to a point of distribution in the heart of their district, and they bring their water by a canal at something like 100 feet above ordnance datum, so that they have to lift 100 feet less than the other companies, and they have no amount of friction to overcome. The result is that those two companies are pumping at half the cost of the other companies, and they have a great advantage in that respect. They also differ in their mode of distribution, or at all events in the mode in which the distribution is effected. The New River Company pump their water by rotatory engines, and so do the Chelsea and Lambeth companies, into reservoirs, and from those reservoirs they take their supply. The East London Company raise their water by a large number of Cornish pumping engines, (as the Southwark and Vauxhall, and the Grand Junction companies, and the West Middlesex, I believe do to a great extent,) and they supply without a reservoir by keeping up the pressure upon the pipes according to their demand, increasing or knocking off the horse power at work according to the varying demands of the day. It so happens that the elevation of the Stanmore reservoirs gives the means of communicating with every one of the reservoirs (except the very high point reservoirs), which are used by all the existing companies, and giving full pressure in every district, always excluding the very high points, which refer to a very small population, perhaps 1/70th of the whole. The highest reservoir of the New River Company is the Maiden Lane reservoir, which is at an elevation of 231 feet 5 inches. I mentioned that the termination of the aqueduct which would be made in continuation of the main aqueduct from Stanmore for the express service of that district will be at 240 feet, therefore I have a difference of 8 or 9 feet for a mile and a half, and I can easily supply that.

But before going to that point, I must state that instead of having as there are now eight different companies supplying eight different districts, it would be convenient, supposing a fresh supply of water were introduced, and the companies purchased or absorbed in any new arrangement, that the whole metropolis should be divided into four or five districts, one being a compound district consisting of one pipe for two districts. The East London and New River should go together, and I have endeavoured to show that by the red marginal line on the plan, which shows the manner in which all those districts which are now distinguished upon the original map by the red colour and the brown colour should go together. Then the Grand Junction, the West Middlesex, and the Chelsea Companies, which you see interlace very much with each other, should also be formed into one district. The Barrow Hill reservoir of the West Middlesex Company should be used for the high portions of the Grand Junction and the West Middlesex districts, and the two reservoirs which supply the lower districts of those two companies should be used as they have hitherto been. The Chelsea Company might be treated in two ways. I propose to take a pipe in continuation of the pipe from Stanmore, from Campden Hill down to the 30-inch main which is the main pipe of the Chelsea waterworks, and join it near the point at which it commences its distribution; all the water would be put into that pipe, and no alteration of pipes would be required. On the southern side of the Thames I propose that the Lambeth and Southwark and Vauxhall districts should be combined; at present you see they not only interlace, but a portion of the district is supplied by both companies distinguished by a sort of neutral tint, the Lambeth district being distinguished by the blue, and the Southwark and Vauxhall by the red, and a portion is coloured

with both colours, showing that in that district both companies have the supply of the water. Then the Kent district, which goes quite to the east on the south side of London, might be a district by itself. Then I have taken the quantity of water which is now supplied, and the probable rate of increase, which I think is the next point in the determination of this question.

6572. (*Mr. Harrison.*) Your view is to deliver the water into the existing reservoirs of the companies, and that there would be no change after that in the present arrangement of their works?—There would be no necessity for changing a pipe as far as the arrangement of the works was concerned. I should in all cases take the pressure at the present fountain heads of distribution.

6573. And you leave the question of constant high-pressure service untouched?—Yes.

6574. In fact any expenditure under that head would be the same in one case as the other, to convert the present system into a high-pressure system?—Yes, that would be a very small expenditure.

6575. (*Chairman.*) You have given us now your views as to the best mode of districting London for the supply of water, what effect do you contemplate that would have upon the existing companies; what is in your mind when you district London in this way?—I propose that all the companies should be abolished, as companies, and that they should be absorbed by a general water commission or a corporation, as it is in Manchester and Glasgow and Liverpool, for the supply of water, and that they should be allowed to levy a compulsory rate upon every house and upon all property. But you will see that by this arrangement every company would have its water exactly as it has had it, and that each company might still continue to distribute as it has done. I do not think that the companies ought to exist.

6576. That is another point; but your own plan would be to annihilate them all?—To absorb them all, guaranteeing to them upon the security of the public rates their present dividends, or whatever might be declared to be upon proper arrangement the fair annual value of their property, or to buy them up.

6577. But supposing it were thought advisable that the existing interests should be left untouched, would your scheme be applicable to such a state of things?—Perfectly so.

6578. Will you be kind enough now to explain to the Commission how the existing interests of all the water companies and their dividends and their status might be retained and your scheme passed?—By the line of aqueduct which will end at Crouch End, below Highgate, water could be conducted to the New River Company's reservoir at Maiden Lane, which is their highest reservoir. In the arrangement which I propose, I propose that all their very low service reservoirs which do not give a proper high pressure should be abandoned. At present the New River Company force their water up through pipes to Maiden Lane. I would put the water into the Maiden Lane reservoir at the top, and the water would go down the pipe instead of being forced up; therefore they would have their water at the highest point to do as they chose with. I further propose to continue the pipe from Crouch End to the reservoir at Hornsey, for the construction of which the East London Company obtained power last session, which is 140 feet above datum. There they may do what they like with it; they may take it down to Lea Bridge if they please. I have estimated the cost of taking it down to Lea Bridge and putting it into their very starting point. The only difference would be that they would get their pressure by gravitation instead of by the exertion of horse power to give it artificially.

6579. You take Crouch End as the end of the aqueduct, but what is the state of matters as it exists at the present moment? how is the water put into that reservoir made available for the purposes of the New River Company?—There would be no reservoir at Crouch End except a mere basin, the reservoir would be at Stanmore. Maiden Lane reservoir which belongs to the New River Company is 231 feet above the ordnance datum, and they pump the water there by steam power into the reservoir.

6580. Where do they draw it from?—From the river Lea. The New River water starts at Hertford from the river Lea, and by the New River they bring it into the heart of their district at an elevation of 100 feet above ordnance datum.

6581. (*Sir J. Thwaites.*) The point is not the mechanical question as to whether you can put the water into the various pipes and mains of the existing companies, but financially how would it be possible for you to carry out your scheme except on the condition that the several water companies were absorbed. You have now brought yourself into the condition of a wholesale supplier, and you have certain existing companies which have statutory powers to supply, and large sources of supply, and unless you absorb those existing companies it is quite clear that they might refuse to take your water, although of much superior quality to that which they supply, and Parliament would never drive them to it?—I have a very strong opinion upon that point, that the companies ought to be abolished by proper arrangements. They deserve well of the inhabitants of London, they have supplied them with water when they would not supply themselves, and therefore they deserve well of the public, and they ought to be properly and handsomely paid for their position in the same way as the old Glasgow Company and the Gorbals Company were paid in Glasgow, and two or three old companies in Liverpool, and the old company in Manchester, which were all paid and handsomely paid by the corporations.

6582. Does not your scheme proceed upon the assumption that the whole of them must be absorbed?—It does. It is not necessary that they should be absorbed, but I should be very sorry to be engineer to a scheme which did not absorb them.

6583. (*Mr. Harrison.*) If not absorbed, would it not be necessary that they should be compelled by Parliament to take your water and to distribute it?—Yes, everybody in London ought to have water, and everybody no doubt gets it more or less, and if they do not pay for it they steal it. That is a state of things which ought not to exist. You ought to place water within reach of everybody, and compel everybody to pay according to the property occupied, which may be considered to be according to their means. I would compel them to pay for so great an advantage. Then all property ought to pay because you reduce the chance of fire. I am able to show very important evidence upon that point. You improve the health of a town by an increased supply of water, and you increase the value of property, therefore all property of all kinds ought to pay a small rate, and for domestic supply specially a higher rate, and in that way you would not have occasion to levy from the inhabitants as large an amount per head as they pay now, to defray the whole cost of this undertaking. I have brought all this before the public in a purely disinterested way, for I am only anxious to give all the information which I possess upon the subject, and I should be sorry to advocate the continuance of the companies. I am so convinced of the great advantage which would result from this water supply being in the hands of a great corporation for the benefit of the whole metropolis, that I would not advocate a scheme which did not include that idea.

The present quantity of water, that is, the average quantity of water which was supplied in 1866 (and I take 1866 for a particular reason), was 95,000,000 gallons. London, as you are aware, has doubled itself in 40 years twice over, and if you are to judge of the future from the past, and there seems to be no present reason for supposing that that proportion will diminish, it will go on increasing at the same rate, and therefore the present population, which is rather more than 3,000,000, will in 20 years be 4,500,000. The increase of population from 1851 to 1861 according

J. F. Bateman, Esq.

5 March 1868.

to the census returns was at the rate of 1·73 per cent. per annum, and the increase in the water supplied from 1856 to 1866 which you see overlaps and includes a portion of the other decennial period, according to the returns of the companies, was rather more than 2½ per cent. per annum, although the population had increased only at the rate of 1¾ per cent. per annum.

6584. (*Col. Harness.*) Had not the companies extended their areas of supply?—I think not, but that would not affect the calculation. They might have extended their area (I do not think they have), they had increased the water supply from 1856 to 1866. Their works of improvement and extension were constructed between 1852 and 1856, and from that time they would very likely have extended their area a little; but from 1856 to 1866 they had not extended their area. The population of the area included in their water supply increased at the rate of 1·73 per cent. and their actual supply increased at the rate of 2½ per cent. The increase of water supplied in 1867 over 1866 was 3·9 per cent., in that year it was 4 per cent. per annum in round numbers greater than it had been; and if the increase in the population between 1866 and 1867 had remained as it was according to the last census, it would have been 1¾ per cent., whereas the whole increase in the water consumption was 4 per cent. If then in 1867 the increase in the population remained the same as it had been in the decennial period ending in 1866 it would be 1·73 as against 4 of increase in the water supply.

6585. (*Sir J. Thwaites.*) You are of course aware that during the exceptional period to which you have referred, the abolition of cesspools, and the adoption of waterclosets to the extent of many thousands in the metropolis, has greatly increased the demand for water?—I daresay it may have done so.

6586. But that increase will not run an equal race with the population for the future, because all houses are adapted for the supply, or as a rule it is so?—No doubt, but we find that from the more luxurious habits, and greater habits of cleanliness, and the use of the bath to a very much greater extent than formerly in all places, the consumption of water is increasing regularly year by year more rapidly than the population. In 1856 the supply was at the rate of 28 gallons per head per day, in 1866 it was at the rate of 31 gallons per head per day, and in 1867 it was at the rate of 32 gallons per head per day. If you take 32 gallons per head per day as the consumption, and estimate the population in 1877, nine years from the present time, at 3,650,000 persons, which it would amount to at the rate of 1·73 per cent., you will want 117,000,000 gallons a day. If you take the increase at the rate of 2½ per cent., you will want 127,000,000 gallons a day at that time; and if you take it at 3 per cent., which with all deference I think ought to be what you should take it at, you will want in nine years from the present time 132,500,000 gallons a day. Judging from the experience of all the places that I know, I think that is about the right amount to take, and my own belief is that when you get water which can be supplied by gravitation, when you include everybody as you ought to do upon the principle which I have laid down, and compel them to pay for water, and therefore give them an inducement to take it and use more than they have done, when you have converted every privy into a watercloset, and when you have water of the softness of Welsh water, in which case you would sell as much again for trade purposes as you do now, that is an under-calculation instead of an over-calculation, and my belief is that before nine years are over you will want more than 130,000,000 gallons a day. However, I have assumed 130,000,000 gallons, because that happens to be the scale on which I devised these works when I first laid them before the Commission, and that seems to me to be the quantity which may be required about the time at which they could now be executed; therefore in the table which is now before his Grace I have allotted that quantity of water as nearly as I could according to the apparent increase in the different districts. 95,000,000 gallons being the quantity in 1866, 35,000,000 gallons more are required to make up the total quantity of 130,000,000 gallons. I have added in round numbers 25 per cent. to the New River Company, whose tenants are not increasing quite so much as the others; I have added 40 per cent. to the East London; 15 per cent. to the Chelsea, which is confined to a limited district, bounded in on both sides, and therefore not likely to extend so much as the outer districts; 50 per cent. to the West Middlesex, which is a large district; 50 per cent. to the Grand Junction, which is in the same position; 50 per cent. to the Southwark and Vauxhall, which is also in the same position; 25 per cent. to the Lambeth, which does not seem to be increasing so much as the others; and 50 per cent. to the Kent, which is a large district to the east, making up 35,000,000, or a total of 130,000,000 gallons.

TABLE A.

TABLE showing the probable Proportion of the first Instalment of 130,000,000 gallons per day required by each Company's District.

—	Present supply (1866).	Proportionate addition.	Estimated requirements in 1875 or 1876.
New River - -	23,000,000	5,600,000	28,600,000
East London -	19,300,000	7,300,000	26,600,000
Chelsea - -	8,000,000	1,150,000	9,150,000
West Middlesex -	8,250,000	4,350,000	12,600,000
Grand Junction -	8,700,000	4,600,000	13,300,000
Southwark and Vauxhall.	12,700,000	6,700,000	19,400,000
Lambeth - -	9,000,000	2,250,000	11,250,000
Kent - -	6,050,000	3,050,000	9,100,000
	95,000,000	35,000,000	130,000,000

I have already stated that it is proposed to divide the metropolis, according to my idea of what it ought to be, into four districts (or into five, taking the Kent district), and those four districts are so evidently convenient that I think you will agree with me that that should be done. Taking the Lambeth and the Southwark and Vauxhall district, I have divided that into a low-lying district and a high-lying district. Then the supply required, according to the figures which I have just now read, for the New River and the East London together, are 55,200,000 gallons in a day; that is the first district. In the second district, in which are included the Grand Junction, the West Middlesex, and the Chelsea, the supply required, according to the same figures, is 35,000,000 gallons a day. In the higher parts of the Lambeth and the Southwark and Vauxhall districts, which are most to the south, the supply required will be 10,000,000 gallons a day, and in the Kent district, which is a further district, and a good deal of it a high district, 9,000,000 gallons, making 19,000,000 gallons, and in the lower parts of the Lambeth and the Southwark and Vauxhall districts near the river, 20,650,000 gallons. The level of the top of the water of the proposed service reservoir at Stanmore, as I have stated, will be 270 feet above datum, or 257½ feet above Trinity high water. I will now take district No. 1, which is the East London and New River district; the water will be conveyed by the aqueduct which I have already mentioned to Crouch End, and from the end of the aqueduct it will be conveyed to the Maiden Lane reservoir, as I have explained, to the new Hornsey reservoir, as I have also explained, and to Lea Bridge. Then the aqueduct will be of the same size as the Loch Katrine aqueduct, and I have taken the price of that aqueduct at 7*l.* a yard, which is a little more than a much more difficult length of the Loch Katrine aqueduct, the Duntreath contract, on which there was a tunnel and deep cutting, and besides that it is all covered, and there are various

bridges, none of which would be required in this work; but in order that I might give you no doubtful estimate, I have taken the actual price of that and added a little to it, and I have put it at 7*l.* a yard, that comes to 184,864*l.* There are some particulars which I think I need hardly go into, as to the level of the aqueduct and of the various reservoirs. If you will refer to the tables which I have put in, you will find that the New River will require 28,600,000 gallons. A 4-foot pipe will deliver 29,395,000 gallons after adding 25 per cent. to the theoretical discharge, as deduced by formula. That 4-feet pipe, with a fall of 7 feet in a mile, which there exists, will deliver 29,000,000 gallons in round numbers, and 28,000,000 gallons in round numbers are required. I have here a piece of pipe (*producing the same*) 5 inches in diameter, which was laid down at Cheetwood, near Cheetham, in the Manchester waterworks, in the year 1851. It was broken by the excavators last month, and I had it sent up to me for the purpose of showing the Commission what the result of the coating of cast-iron pipes by Dr. Smith's process is. I introduced the process into Manchester for the first time, and I coated all the pipes myself, and that pipe has been down 17 years. Externally it is just as fresh as the day it was put down, and internally it is almost in its original condition after 17 years' wear.

6587. (*Mr. Harrison.*) Have you reason to believe that the rest of the pipes are in as good condition as that?—Yes; all the pipes which I coated myself or under my own superintendence are as good as this, and I have seen some which have been taken up that were even better than this. But the pipes which were coated in Glasgow were coated by an ironfounder, and I will never again in a great contract allow the ironfounder to coat pipes. I will do them all under my own superintendence because they are so much better done. The mode of coating is this:—The Manchester pipes after being cast by the ironfounder, as soon as they were dressed, the sand dressed from them, and they were clean, and while they were warm, were coated with oil or immersed in oil, and in that condition they were sent to the corporation. They might then lie for some time, and they would contract no rust—it is very important to prevent rust—and then they were coated by being first heated up to about 300 degrees of temperature in a stove, and taken out of that stove while they were hot and immersed in a cauldron of boiling coal-pitch (after the naphtha was distilled from it) and oil—and that also heated up to 300 degrees of temperature; they were allowed to remain in this for a few minutes and then were gradually drawn out and cooled, and the pipes become coated with a perfect black *glaze.* The result of the coating in the Glasgow case was that the quantity of water which was discharged whilst they were quite fresh, from passing over this surface, which is like glass, was more than 50 per cent. in excess of the calculated results according to the formulæ; and although they were badly coated and not done with the care with which I should have coated them (and no ironfounder does it as it ought to be done), and many of the pipes have become rusty, they are now, through a pipe which according to the formulæ ought to discharge 19,600,000 gallons a day, discharging about 23,500,000 gallons or 24,000,000 gallons day by day.

6588. (*Sir J. Thwaites.*) Is that increased discharge caused by the small amount of friction in the pipes?—I suppose it is so. I only state the actual fact. So that adopting the proper mode of coating and reasoning from experiments, and from the actual result in the case of the Glasgow pipes, we are justified in taking upon those pipes at least 25 per cent. in excess of the computation which the mere formulæ would give. The East London supply which will be taken from the end of the aqueduct at Crouch End by another line of pipes would discharge an equal quantity of water, or more in point of fact, into their new Hornsey reservoir and deliver the water at Lea Bridge with a remaining effective pressure of 190 feet in the pipes. I believe they only lift their water about 140 feet, and therefore they would have an advantage of 50 feet of additional pressure, together with the full supply of water which would be required. I need not go through the details of the estimate, but you will find in the tables before you that that comes to 70,270*l.* The existing service reservoirs of the New River Company will be sufficient for their district. For the East London district it will be necessary to add to their new Hornsey reservoir, or to construct a new one of the capacity of some 14,000,000 gallons a day. I have only allowed in my scheme, as common to this as well as to any scheme, half a day's supply for the night supply, because those large pipes will be delivering their water constantly for 24 hours, and inasmuch as the demand at particular hours of the day is greater than the average demand during the period when the water is delivered, you are obliged to regulate that by having a reservoir into which the night water will be discharged for the purpose of keeping up the extra demand upon the pipes in the course of the day. Therefore I have allowed for service reservoirs where the existing reservoirs are not sufficient. From information which was laid before the committee on the East London Water bill of last year, and from other information of a public character, I have obtained the exact capacity of the various reservoirs, and have taken them into account whenever they were large enough.

J. F. Bateman, Esq.

5 March 1868.

Then No. 2 district, which is the Grand Junction and the West Middlesex and Chelsea combined, will receive this water by a 4-foot pipe from the service reservoir at Edgware, which will communicate with the Campden Hill reservoir of the West Middlesex and Grand Junction companies, and with the Barrow Hill reservoir of the West Middlesex Company. From the Campden Hill reservoir a 3-foot pipe will be taken to communicate with the Chelsea Company to join their 30-inch main, so that they will get the full additional quantity of water. The quantity required for the whole of this district according to the figures that I have given before is 35,500,000 gallons. The volume of water which a 4-foot pipe will discharge is 35,300,000 gallons, therefore that will be sufficient. Then the estimate for the 4-foot pipe and the 3-foot pipe together is 118,650*l.*

With regard to the No. 3 district, which comprises the higher parts of Lambeth and the Kent district, the quantity of water which they require is 19,100,000, the Kent district requiring 9,100,000, the Southwark and Vauxhall and the Lambeth together for this district 10,000,000. As to the difference of level I have taken all this into account, and I need not trouble the Commission with it. Those districts can be supplied with water from the Edgware reservoirs delivered into Streatham Hill reservoir, which only allows a fall of 4 feet per mile. The Streatham Hill reservoir is 197 feet high, and therefore it is within about 53 feet of the reservoir at Edgware, a considerable distance off; but allowing for all that, a 4-foot pipe brought from Edgware over the river into Lambeth will bring all the water which is required for the two districts. A 4-foot pipe is as nearly as may be double the area of a 3-foot pipe, and therefore it is equivalent to the service of two 3-foot pipes, and a 3-foot pipe to Streatham will deliver all the water which is required for that district; it will deliver 10,438,000 gallons a day, about 10,000,000 gallons being required; and a 3-foot pipe from the same point of bifurcation to Blackheath, for the supply of the Kent district, will deliver 13,000,000 gallons a day, 9,100,000 being all that is required, therefore those pipes are more than sufficient for the district. The estimate for that, including 50,000*l.* for the special bridge over the river Thames for the conveyance of the pipes, is 240,800*l.*

The No. 4 district, which is the low-lying district now supplied by the Southwark and Vauxhall and the Lambeth companies jointly, requires 20,650,000 gallons. One 4-foot pipe delivering the water into the reservoir at Putney, which is at present the Chelsea waterworks reservoir, and which I propose

J. F. Bateman, Esq.

5 March 1868.

to appropriate no longer to the supply of Chelsea, but to the supply of the Southwark and Vauxhall, will deliver 27,000,000 gallons to that reservoir, 20,650,000 gallons being what are required, and the cost is 162,750*l.* The summary of the whole estimate, adding all those sums together, and additional service reservoirs in the several districts, where the existing reservoirs are not sufficient for the purpose of regulating the supply in the day by impounding that which will come from the pipes in the night, is 1,059,810*l.*, including the service reservoirs at Edgware, the estimate for which is 237,438*l.*

I may perhaps observe that evidence has been given before the Commission that the cost of the reservoirs at Edgware would be from 800,000*l.* to 1,200,000*l.*, the mean of that is 1,000,000*l.*, but the actual cost upon a very full estimate indeed and double the real value of the land is less than one quarter of that amount. It was also stated that the cost of the re-arrangement of the pipes, and of conveying the water from the Edgware reservoir to the various different districts from whence it will have to be distributed, would be 2,000,000*l.*; the actual estimate, and it is a very proper estimate, as I think anybody will be able to see, is 750,000*l.*, and not a single pipe requires to be altered; the only change will be that pipes which will now become useless or too large for the various purposes of the supply may be taken up and applied to other purposes, but the water you see will be delivered into the nuclei of supply of the East London and New River companies just as they now supply it. It will also be delivered into the Lambeth district just in the same way, and it will be delivered into the Grand Junction and West Middlesex district exactly in the same way. Chelsea will be altered, for it will receive its supply direct from Edgware or from the Campden Hill reservoir, instead of taking it from the reservoir on Putney Heath, by a communication with the 30-inch main which conveys the water into Chelsea being made on the north side of the river, with a pipe from Campden Hill 36 inches in diameter. The Putney Heath reservoir will then be no longer appropriated to the supply of Chelsea, but it will be appropriated to the lower parts of Southwark, Vauxhall, and Lambeth, by a pipe taken from it and joining the Southwark and Vauxhall pipe at a point which it intersects on its way from Hampton to Battersea; a mere junction will do the whole thing. The Kent district will have a new reservoir near Blackheath in close proximity to the existing reservoir in Greenwich Park, with which it can be communicated, or a very slight additional bit of piping will put it directly in communication with the pipes which perform the service of that district. The change which will follow will be that the pipes from Thames Ditton into the district, which are nearly 20 miles altogether, will be rendered unnecessary. They are of various sizes, and the larger pipes which will be too large for their purpose may be taken up and smaller ones put down, or they may be used in some other way. Various pipes from Hampton also will be rendered unnecessary to a great extent, for they will be too large for that district, and they may be either continued or taken up and smaller ones put down. So that everything will be accomplished without disturbing any existing arrangements, and the Kent district, which it was confidently asserted could not be supplied at all, will be supplied with almost more effect and less cost than any one of the other districts, except those which are in close proximity to the large reservoirs.

6589. (*Chairman.*) With regard to the constant service, do you propose to give the Commission any evidence with reference to the constant service for the supply of London?—I had not intended to do so, but I shall be very happy to hand in a reprint of a paper upon the subject, which I read before the National Association for the Promotion of Social Science, and which I think will exhaust the subject pretty nearly (*handing in the same. Vide Appendix I.*). I may also mention that a great deal of evidence upon this very question was given for the East London Waterworks bill last session before a committee of which Mr. Ayrton was chairman, to which I may have occasionally to refer. I may state that my own opinion is that a constant water supply under high pressure in the existing state of the plumbing in London would be almost impossible, and that it is necessary that very stringent powers be given to the companies or to a corporation, if it had the administration of the water, to compel all the parties to put their water fittings into perfect order before the constant supply was given. Even the Welsh district would be almost insufficient to supply London under the constant system, as the fittings are now; but if proper care be taken that the fittings be all properly put in order, and a very strict supervision exercised, I find as a matter of experience that towns supplied under the constant system do not take more water than those which are supplied under the intermittent system. But one great and the principal source of waste is the watercloset, and also baths, which are now very largely introduced; in fact where the water is abundant and good there is sure to be a larger demand upon it, and a much greater quantity of water used than where it is insufficient and hard, and otherwise objectionable. It will therefore require on the part of anybody who may have the future administration of the water to be very stringent, and very careful in seeing that everything is properly adapted for the reception of the constant supply, otherwise London cannot have what I consider to be one of the greatest blessings, a constant supply.

6590. (*Sir J. Thwaites.*) With that efficient supervision you see no difficulty in applying the principle of constant supply?—I do not; I do not know how many towns I have supplied with water, but I have supplied I think something like 2,000,000 of people, and there are not 150,000 out of the whole of them who have not the constant supply.

6591. If with the constant supply you have the necessary inspection which you have referred to, and the mechanical arrangements suitable to constant supply and constant pressure, are you of opinion that it would rather economise than otherwise the quantity of water used?—I think it would, and if every adjustment is properly made it ought to economise it.

6592. Do you know the waterworks at Hull?—I am not acquainted with the waterworks at Hull, but I may state that in Manchester, where there are very few waterclosets in comparison to the population, and where baths are not common, the large bulk of the population consisting of the working classes, the consumption of water is now increasing. It was about 21 gallons per head per diem, it is now about 23 or 24 gallons per head. The consumption of water in Glasgow is 50 gallons per head per diem, where water fittings are as bad as they can be, as bad as they are in London (and that is about saying the worst thing for them), and the waste is very great indeed; I forewarned them against this, and for a time very active supervision reduced the waste after the introduction of the Loch Katrine water; but they consider that they have an inexhaustible supply and that it tends to sweeten the Clyde and flush out the sewers, and they allow the waste to go on, but all that might be corrected.

6593. Under the present system of supply in London, is it not the case that the companies shut off a certain area of distribution of water during certain hours in the day, and in case of a fire, unless the water is turned on to that district, there is no means of suppressing a fire in the metropolis?—That is so.

6594. But with the principle of the constant supply you would have water in every district, and although you may not be able to use it from a hydrant, still you would constantly have water which could be pumped upon a fire which might occur in this district?—Yes, the advantage of a constant supply in case of fire is very great indeed, it can hardly be overestimated, and I have the means of showing the Commission the result of an abundant supply of water

under high pressure in Manchester, from a report as late as the 8th of January 1868.

6595. What height can you throw water from your mains by means of hose?—When I laid out the supply of water in Manchester it was the first city which obtained the power of levying compulsory rates upon all property and upon all houses, and I thought it was only right that warehouse property, for instance, and other valuable property which did not take water for domestic purposes, should have the best possible protection and the greatest advantage that could be conferred upon them for their public rate, and I therefore laid out the pipes in the centre of Manchester, where the property was the most valuable, specially with a view to the extinction of fire and the protection of property, and there is no large block of buildings in Manchester which is not commanded within 100 yards by at least 20 fire-cocks. Fire engines have been discontinued, except as omnibuses to carry men and utensils. The pressure is such as will throw the water from the street over the highest building. The pipes are interlaced in such a way that the fire-cocks are not dependent for their supply upon one particular main, but the various mains are so interlaced that if one should be out of order or should be overdrawn other pipes would be able to deliver water. The result of that state of things is pretty much this—I have here before me a return of the amount of property destroyed and property saved on occasions when fires have occurred, from 1844 to 1867. The water was introduced into Manchester about 1851, but it hardly got into full use till about 1853. We had to change from the old intermittent system, as bad as anything could be, to the constant system, and we were very careful in taking it by districts, so that every district should be brought under the surveillance of proper officers, district by district, before we admitted it to the advantage of the constant supply, and in that way it was that we reduced the consumption so much. The per-centage of property destroyed from 1846 to 1850, before the introduction of the water, was 21·3 per cent. of the value of property attacked by fire. The amount saved out of such property was 78·6 per cent. From 1851 to 1855, Manchester, for half the time at least, not having advantage of high pressure, and for the latter two years of the time having it, and therefore it would be partly under the old system and partly under the new, the per-centage of property destroyed was 12·9 per cent., and of that saved 87 per cent. Then came the advantage of the constant supply and high pressure, with a full water supply, and from 1856 to 1860 the per-centage destroyed was only 7·7 per cent., being only one-third the amount which was destroyed before the introduction of the fresh water supply, and the amount of property saved was 92·2 per cent. From 1861 to 1865, the amount of property destroyed was 6·7 per cent., and the amount saved was 93·2 per cent. I do not think it is possible to have a stronger elucidation of the great advantage which arises in case of fire from a full water supply.

6596. Then you have reduced the loss from 21 per cent. to 6·7 per cent.?—Yes, taking the two lowest, it is from 21 to 7, and the increase in the amount of property saved is from 78·6 to 93·2. With the permission of the Commission I will hand in the following table (see p. 378):—

6597. (*Col. Harness.*) With regard to the loss by waste under constant supply, have you any experience of the effect of the delivery of water by meter in checking waste?—Yes; in the paper which I have handed in, there are a great many examples of that. The difficulty with the meter is the small quantity of water and the intermittent way in which it is drawn for house supplies. You could hardly supply a meter to individual houses, but you might put one to a district, and you might then see what the district was wasting, and in that particular district which was taking more than its normal supply you might introduce special investigations. That is one of the ways in which we manage to detect waste. The only difference between Manchester and London would be this, that having, for the purpose of showing how completely water could be supplied without disturbing the present arrangements, adopted the service reservoirs which now exist, in some cases they would not have quite the same amount of high pressure which we have in Manchester, but the higher service reservoirs which I propose to adopt are still high enough to give a very considerable pressure, and in most cases quite sufficient.

6598. (*Sir J. Thwaites.*) What is your head in Manchester?—I tried a number of experiments, and actually measured the height to which we could throw water, and I think we can generally throw water in almost every part of Manchester to a height of about 118 feet from the pipe, if I recollect rightly. By opening a fire-cock I have ascertained, by estimation and by a theodolite, that the height to which the water has been thrown has varied from 118 to 120 feet.

6599. With regard to the condition of the mechanical arrangements for the supply of water in the metropolis, what, in your judgment, would be the cost per house of putting them into such a state as to resist the pressure, and adapt them to the constant supply?—If the fittings are now, with the exception of the tap itself, such as are ordinarily put in, they would now be quite sufficient. I have changed the supply from intermittent to constant supply in a great number of towns, and I never heard anything like a complaint of the bursting of pipes by introducing the new system; in London plumbers are allowed to do whatever they choose, and not one of the companies exercises the slightest supervision over them; the probability is that they put in perhaps rather too strong than too weak fittings; but in all works with which I am connected I arrange the strength of the pipes according to the size, and according to the pressure, and the kind of tap to be used, and we require the plumbers to put them in. In very many cases corporations cannot do that, from the public outcry that is made; but in all private companies of which I can get the control, the companies do all their plumbing work themselves at a fair price, so as not to injure the plumber, and they make a considerable profit, and put in nothing but the best fittings.

6600. Do they use leaden pipes?—Yes, they use leaden pipes; wrought-iron pipes will not do; they corrode and burst. I tried them in my own house, and that was the result; but with leaden pipes and the best taps which can be employed, the whole cost of introducing water into a cottage house, for instance, is about 12*s.* to 15*s.*

6601. Is that the whole cost to make it fit for the constant supply?—Yes, that is the whole cost if you have to do it *de novo*, and surely it will not cost more to fit it for the constant supply than to do the whole thing afresh. Supposing there is any doubt about it, if you strip it all away, and put in a fresh thing, it will only cost 12*s.* to 15*s.* in a cottage house.

6602. Then are we to understand that the infirmity of the old system is rather due to the condition of the taps than to the pipes?—I believe that is the case everywhere. It may be that having been put in without supervision some of the pipes are too weak and will burst, but they will find themselves out very shortly; they may occasion a little annoyance in the first instance, but in the course of a week a weak pipe will tell for itself, and will burst, and you will have to put a stronger one in. Take any house in this neighbourhood, my own house in Great George Street, for instance, where the water is introduced into cisterns, I should make no alteration; I should use the pipes as they are. I would not incur the expense of 8*l.*, as has been mentioned, but I should have a plumber to see to the pipe which conveyed the water from the street, and if it was at a higher pressure, and by the arrangements which I now propose it would not be at a higher pressure, but if at a higher pressure I might change the ascending pipe from the street to the cistern, nothing more, and put a stop tap upon

ANNUAL COMPARATIVE TABLE of the NUMBER of FIRES that have been attended within the CITY OF MANCHESTER, showing the Origin of the Fires, Amount of Property at risk, Extent of Damage, and Value of Property not destroyed, giving the Per-centage of the Amount destroyed for the last 24 Years.

Period.	Number of Fires attended within the City.			Origin.												Time of Discovery.		Amount of Property at risk, insured or not.								Amount of Property destroyed.				Amount of Property not destroyed.			
																		Buildings.				Stock.											
	Total.	Serious.	Slight.	Boiling over of oil and chemicals.	Candles, sparks from fires, and lucifers.	Children playing with fire.	Incendiarism.	Doubtful.	Friction of machinery.	Gas, defective fittings.	Moveable gas jets left burning.	Using lights while intoxicated.	Spontaneous ignition.	Timber too near flues and fireplaces.	Unknown.	Day. Between 6 a.m. and 6 p.m.	Nt. Between 6 p.m. and 6 a.m.	Number insured.	Amount.	Number not insured.	Amount.	Number insured.	Amount.	Number not insured.	Amount.	Total Amount at risk.	Buildings.	Stock.	Total.	Per cent. destroyed on the amount at risk.	Buildings.	Stock.	Total.	Per cent. not destroyed on the amount at risk.
1844	127	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		71	£ –	56	£ –	52	£ –	75	£ –	£ 450,332	£ 38,793	£ 143,582	£ 182,375	40·4	£ –	£ –	£ 267,957	59·5
1845	137	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	90	–	47	–	60	–	77	–	495,261	10,137	56,582	66,719	13·4	–	–	428,542	86·5
1846	114	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	81	–	33	–	53	–	61	–	260,873	8,006	23,153	31,159	11·9	–	–	229,714	88·
1847	112	–	–	4	51	–	2	–	6	–	2	–	3	24	20	–	–	83	–	29	–	51	–	61	–	198,778	10,459	32,194	42,653	21·4	–	–	156,125	78·5
1848	100	–	–	7	33	–	1	–	4	–	5	–	11	17	22	–	–	64	–	36	–	50	–	50	–	203,163	13,909	24,855	38,764	19·	–	–	164,399	80·9
1849	114	–	–	2	44	–	–	–	3	3	–	–	13	24	35	–	–	73	–	41	–	55	–	59	–	173,186	5,783	19,585	25,318	14·6	–	–	147,868	85·3
1850	140	–	–	4	52	–	–	–	5	7	–	–	11	31	30	–	–	97	–	43	–	74	–	66	–	348,209	22,377	92,938	115,215	33·	–	–	232,994	66·9
1851	130	–	–	2	55	–	–	–	4	5	–	–	13	24	29	–	–	106	–	26	–	62	–	70	–	478,803	13,016	39,679	52,695	11·	–	–	426,108	88·9
1852	163	–	–	7	68	–	2	–	4	8	–	–	10	32	32	–	–	116	–	47	–	72	–	91	–	319,623	11,998	34,750	46,748	14·6	–	–	272,875	85·3
1853	185	–	–	6	67	–	1	–	9	4	–	–	17	38	43	–	–	132	–	53	–	104	–	81	–	394,254	3,529	8,711	12,240	3·1	–	–	382,014	96·8
1854	202	–	–	5	50	–	–	22	7		–	–	8	29	75	–	–	169	–	33	–	149	–	53	–	966,751	20,679	149,997	170,676	17·6	–	–	796,075	82·3
1855	217	–	–	7	62	–	–	–	7	4	–	–	16	52	69	–	–	163	–	54	–	120	–	97	–	541,092	12,179	56,373	68,552	12·6	–	–	472,540	87·3
1856	137	–	–	2	49	–	–	–	5	2	–	–	10	28	41	–	–	119	–	18	–	115	–	22	–	545,898	9,503	34,958	44,461	8·1	–	–	501,437	91·8
1857	194	–	–	1	72	–	–	2	5	6	–	–	8	56	44	–	–	184	–	10	–	166	–	28	–	546,757	7,125	23,112	30,237	5·3	–	–	516,520	94·6
1858	174	–	–	1	68	–	–	–	6	3	–	–	2	38	56	–	–	132	–	42	–	112	–	62	–	608,544	13,454	40,161	53,615	8·1	–	–	554,929	91·8
1859	200	–	–	4	93	–	–	–	7	2	–	–	11	40	43	–	–	153	297,143	47	6,958	110	344,259	90	14,860	663,200	5,228	17,329	22,557	3·4	298,873	341,790	640,663	95·5
1860	217	–	–	7	78	–	–	1	14	1	–	–	5	46	65	–	–	164	160,271	53	8,883	147	415,207	70	8,467	592,828	20,003	58,615	78,618	13·2	149,151	365,059	514,210	86·7
1861	256	–	–	4	81	–	–	2	11	4	–	–	12	54	88	–	–	190	224,108	66	23,676	140	494,715	116	87,674	830,173	34,241	119,944	154,188	18·5	213,540	462,445	675,985	81·4
1862	201	–	–	2	83	–	–	4	7	4	–	–	5	52	44	–	–	154	232,144	47	6,070	111	398,332	90	7,889	644,435	9,942	28,110	38,052	5·9	228,272	378,111	606,383	94·
1863	220	27	193	5	54	6	7	–	3	15	7	8	8	76	31	79	141	140	185,990	80	24,216	111	543,763	109	27,619	781,588	8,342	16,650	24,992	3·1	201,864	554,732	756,596	96·8
1864	266	23	243	4	94	17	4	–	6	13	7	12	19	65	25	104	162	193	208,931	68	19,275	176	530,397	87	126,612	885,215	6,087	14,453	20,540	2·3	222,119	642,556	864,675	97·6
1865	250	31	219	6	71	12	5	–	4	12	4	7	13	55	61	95	155	168	205,389	78	50,615	118	420,709	131	77,608	754,321	4,178	20,214	24,392	3·2	251,826	478,103	729,929	96·7
1866	287	20	267	7	98	11	1	2	7	11	10	14	20	63	43	103	184	187	369,100	99	80,516	131	1,155,500	155	154,635	1,759,751	36,140	136,503	172,643	9·8	413,476	1,173,632	1,587,108	90·1
1867	278	24	254	6	91	17	3	3	6	10	8	9	20	56	49	95	183	177	304,757	96	32,670	117	637,129	159	70,828	1,045,384	7,940	17,665	25,605	2·4	329,487	690,292	1,019,779	97·5
Annual average for 5 years, 1846 to 1850	116	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	79·6	–	36·4	–	56·6	–	59·4	–	236,841	12,106	38,525	50,621	21·3	–	–	186,220	78·6
„ „ 1851 to 1855	179·8	–	–	5·4	60·4	–	·6	4·4	6·2	5·4	–	–	12·8	35	49·6	–	–	137·2	–	42·6	–	101·4	–	78·4	–	540,104	12,280	57,902	70,182	12·9	–	–	469,922	87·
„ „ 1856 to 1860	184·4	–	–	3·	72·	–	–	·6	7·4	2·8	–	–	7·2	41·6	49·8	–	–	150·4	–	34·	–	130·	–	54·4	–	591,445	11,062	34,835	45,897	7·7	–	–	545,551	92·2
„ „ 1861 to 1865	238·6	–	–	4·2	76·6	7·	3·2	1·2	6·2	9·	3·6	5·4	11·4	60·4	49·8	–	–	169·	211,312	67·8	24,770	131·2	477,583	106·6	65,480	779,146	12,558	39,874	52,432	6·7	223,524	503,189	726,713	93·2

NOTE.—The particulars required in the blank spaces for the years prior to 1859 cannot be supplied, as the additional information returned since that time was not provided for in the original Fire Tables.

it; and then if I had any tap which was liable to run the water to waste I should change the tap and put a better one. That is all I should do, and that is all anyone would do with an old house; but if you were coming to a new house, in a great number of cases you would do without a cistern, because under the constant supply system a cistern is not necessary. Of course if the water should be shut off for a few hours, in order to attach any of the services, it is convenient to have a cistern, but it is not necessary; and the idea of spending 8*l.* or 10*l.* upon a house is preposterous. I am not speaking now as an engineer only, but I am speaking as a director of water companies, and I have had to do the whole thing, and know all about it. In answer to a question which has been put to me, with regard to how much the waste of water could be reduced, I may state a fact which occurred at Stockport. I happened to be the chairman of the Stockport Waterworks Company. There were some cottages which were supplied with waterclosets, and without any meters. A meter was put down by the gentleman who owned the property, and he paid by meter, and it was found that they took 80 gallons per head per diem. He was so astonished and so annoyed at having to pay such an amount for the water used, that he did away with the waterclosets, and he was supplied by meter for six months without waterclosets, and the consumption for other purposes than waterclosets was found to be 12 gallons per head per diem; so that waterclosets are the great consumers of water, unless they are of the best possible construction. Those were common syphon closets.

6603. (*Col. Harness.*) They must have been of a very vicious construction?—Yes, they are just the things which are introduced by local boards all over the country, and it requires proper supervision and proper authority to be vested in the parties who have to deliver the water in order to protect themselves against waste.

6604. What would you suppose to be the proper supply of water per head for waterclosets, would it be five gallons per day?—I should think that would be very abundant indeed; by the system which I now propose the water will be delivered to everyone. With regard to the existing system of supply to London, I will not take the Commission through the next amount, which is 40,000,000 gallons more, to bring it up to 170,000,000 gallons, but I will explain why I have taken 170,000,000 gallons, and I am going by-and-by to show you the cost of obtaining the extra 35,000,000 gallons over and above the existing supply, by pumping it from the Thames or getting it from the Lea, as compared with the cost of getting that same quantity of water, 170,000,000 gallons in gross, from Wales. In the evidence which had been laid before the Commission by some witnesses who ought to be very competent to give an opinion upon that point, they state that taking the Lea and the Thames together, 170,000,000 gallons may be withdrawn before the necessity for constructing storage reservoirs on the Thames arises, and therefore I have taken the cost of obtaining the water from the Thames and from the Lea under those circumstances with nothing more to do than to put down additional pumping engines and lay additional pipes, as compared with the cost of obtaining the same quantity in gross from Wales. I have gone all through and estimated in the same detail how much that would cost, and the detail is all upon the papers which I will lay before the Commission, including additional quantities up to 230,000,000 and 300,000,000 gallons per day.

I may state generally as I did before that I have had worked up in these various gradations the cost of obtaining water from the Thames and the Lea combined, and from Wales; and before I go through that I may state that I have examined the statements which have been made by the various witnesses who have spoken upon the capabilities of the Lea, and I find that it is cheaper to obtain water from the Thames than to incur the expense which those gentlemen give for obtaining it from the Lea. That I could show, and it is as well that I should do so, because I feel in this position, that inasmuch as I cannot undergo a hostile cross-examination, I am bound to make good every assertion I make, and although it may be tedious to the Commission, I am afraid I must ask you to bear with me whilst I show the ground of every assertion, that I may not be taken to have made any assertion without having ground for it. There were various estimates given, and perhaps I may as well state them. One was that an additional 10,000,000 gallons of water could be obtained from the Lea by an expenditure of from 300,000*l.* to 400,000*l.* on reservoirs. Then there was another, that 70,000,000 gallons could be obtained by an expenditure of 1,250,000*l.*, exclusive of compensation to mills and streams, the whole river having to be bought up if that amount of water had to be obtained. If you take 10,000,000 gallons additional, which is all they propose to take, there is not much difference between 10,000,000 gallons at 300,000*l.* and 70,000,000 gallons at 1,250,000*l.* with the additional compensation. In fact the 70,000,000 in gross would be rather the dearer arrangement of the two, and therefore I have taken the cheaper one, and allowing for the impounding reservoirs, for the engine power to raise 10,000,000 gallons, and for the annual cost of pumping, which I will show by-and-by, I find that the cost of obtaining that quantity of water, 10,000,000 gallons additional from the Lea, would be 597,000*l.* in round numbers, and that the cost of obtaining the same quantity of water from the river Thames would be only 504,000*l.* Therefore it is cheaper for the East London Company, as they thought last year, (and I advised them to do so,) and for the New River Company, to go to the Thames than to endeavour to get the additional water which they want from the Lea. I also know from sources of private information which were all brought out in my examination before the Committee on the East London bill last year, that the river Lea only supplied about 15,000,000 gallons a day for a considerable period during the summer of 1864, when 21,000,000 gallons, or something like that, from 19,000,000 to 21,000,000 gallons were actually being supplied, or were required, and every drop of water was pumped out of the Lea. The East London district had to be put on short commons for a good many days, and whatever was in the Lea, whether it was water pure, or water mixed with sewage or sewage itself, every drop was taken out, and it is the opinion of some who know the Lea well, that no material additional quantity of water could be obtained by impounding reservoirs beyond that which has already been taken; but however that may be, I find that it is cheaper to go to the Thames than to take it from the Lea, and therefore, in all the calculations which I am endeavouring to lay before the Commission I will assume that the additional water shall be taken from the Thames. In estimating the cost of obtaining water from the Thames by the existing companies, I have to ascertain, if I can, the expenses which are now incurred in pumping and in filtering. I have had some difficulty in doing that. It has been ordinarily assumed (I do not know upon what ground) that something like 80,000*l.* a year was spent by all the companies upon pumping, and in addition to that there was the filtering. There are public returns which are made every year to the town clerk of London, and deposited with him, all of which I have extracted, but they are given in such a way that nothing can be made of them, or scarcely anything. Earlier, when they were first given, there were some returns given in such detail that you could make something of them, but latterly they have been put in such a form that you can scarcely make anything of them, and for reasons which I daresay can be very well understood I have ton been able to obtain information from the companies themselves; I have therefore been obliged to go into a considerable amount of investigation in order to determine as nearly as I could the actual cost now incurred in pumping and in filtering. I find that the cost of

J. F. Bateman, Esq.

5 March 1868.

pumping has been given by various gentlemen, and that they all agree in almost every respect. Before Lord Robert Montagu's committee on the best means of disposing of the sewage, three or four years ago, two Cornish engineers appeared, and they gave the cost of raising the water at a price which I believe is equivalent when worked out to 20*s.* 10*d.* for each 1,000,000 gallons lifted 100 feet; they give 2*s.* 4*d.* and 2*s.* 6*d.* per 1,000 tons raised 50 feet, but I have worked it into a more convenient form, that the cost of 1,000,000 gallons lifted 100 feet is 20*s.* 10*d.* In the evidence which was given before you by Mr. Hawksley he gives the cost of pumping at a farthing per 1,000 gallons lifted 100 feet, and that works out to exactly the same figure, 20*s.* 10*d.* Then I happen to know from other sources which I cannot quite state, that the horse power in actual working, and in the case of the most economically worked engines in London, comes to 1*s.* an hour per horse power, and that worked out into the same figures comes to a fraction over 21*s.* per 1,000,000 gallons lifted 100 feet; so that if we take 21*s.* as the actual cost, with the best constructed engines, that will be the amount. Then I have compared that with the actual cost of working in the Liverpool works, where everything is done certainly as well as it can possibly be done, and there the cost of working, if coal were the same price which it is here, would be about 24*s.* or 25*s.* for the work done. I estimate 20*s.* 10*d.* I have taken also another engine which is supposed to be the crack engine in the country, and supposed to do the greatest amount of work, and in that case it would come to 31*s.* if the price of coal were the same; but they use very inferior material, and the duty done by each engine is so much less than the duty performed here, that that properly worked out brings it very much back to the same cost at which the work is performed in London, so that I think I have good ground for taking 21*s.* as the actual cost of raising the water.

6605. (*Mr. Harrison.*) Do you include interest on capital in that?—No, that is the net cost, it includes the ordinary repairs, but not the renewals of engines or the renewals of boilers, but just ordinary repairs. Messrs. West and Hocking, who gave evidence before Lord Robert Montagu's committee, gave it at that price. At the East London works it comes to 21*s.* 0½*d.*, or to 18*l.* 5*s.* per horse power per annum, for engines working night and day, that is excessively low.

6606. In answer to a question which I put to Mr. Quick, the engineer of the Southwark and Vauxhall Company, he stated that the cost is 13*s.* 10*d.* for raising 1,000,000 gallons 100 feet, and he promised when he was here to ascertain the exact fact from their books, this is what he states, including coals, oil, tallow, and wear and tear?—This sum appears to include the same items which are supposed to be included in the other. However, I have taken 21*s.* as the cost. I have before me a table only received this morning from the Liverpool Corporation Waterworks, from Mr. Duncan, who certainly does his work remarkably well, and where one of the engines is one of the best in the whole country, the Green Lane pumping engine; and there the average cost of lifting 1,000 gallons 100 feet high, which is the figure Mr. Hawkesley gave you, amounts to about three farthings, or about three times Mr. Hawkesley's price; but the Green Lane engine amounts to ·239 of a penny, and at the Windsor station, where there is also a very good pumping engine, it comes to ·289 of a penny, which is a trifle over a farthing, therefore I think 13*s.* 10*d.* is a very exceptional price; and considering that all the engines are not of that very superior description, and that that does not accord with any other information which I have received, I am not disposed to vary from the 21*s.* per 1,000,000 gallons raised 100 feet. There are a good many other instances, and which all come to about the same price, and I cannot think that that can be far off the actual cost on the average, but of course there may be exceptional cases. Then I had to ascertain the existing cost incurred in pumping and the existing cost of filtration. The cost of filtration varies in London from one-eighth of a penny per 1,000 gallons to a halfpenny per 1,000 gallons, and several of the larger companies work it at one-eighth of a penny per 1,000 gallons, and to two of the companies it costs a halfpenny or rather more than a halfpenny per 1,000 gallons. That is from evidence which has been given before the Commission, and I have therefore taken it at one-sixth of a penny all through, in all the calculations which I have made. I may say that one-eighth of a penny amounts to 19,000*l.* a year, for each 1,000,000 gallons, one-sixth of a penny amounts to 25,000*l.* a year, and a halfpenny amounts to 76,000*l.* a year, and I have taken one-sixth of a penny, which is 25,000*l.* a year. The cost of pumping and the cost of filtering to the existing companies for the amount of water which they at present deliver I have taken at 120,000*l.* a year, and I want to show my ground for doing that. The Chelsea, the Grand Junction, and the Southwark and Vauxhall companies in 1866, which is a year in which we have certain particulars before us which enable us to deduce conclusions, raised about 29,000,000 gallons a day, at a cost of 46,368*l.* per annum. All the companies drawing water from the Thames together with the Kent Company supplied at that time 52,000,000 gallons per day, and the East London and the New River together 42,000,000, making a total of 94,000,000. Then as a rule of three question, if 29,000,000 cost 46,500*l.* a year, 52,000,000, the quantity raised on the south side of the river, would amount to 83,300*l.* a year. The East London and the New River companies do their work at half the cost of the other companies, from reasons which I have already given, and at half that cost in proportion to the quantity raised it would come to 33,640*l.*, being a total of 116,940*l.* The present horse power employed in London by the existing companies is about 12,000. The cost per horse power of the actual power in use is 1*s.* a day of 24 hours for 365 days in the year, or 18*l.* 5*s.* per annum. It is difficult to determine how much may be actually in use throughout the whole period; but assuming one half to be in use, that would be 6,000 horse power in actual use, and at 18*l.* 5*s.* per horse power that would come to 108,000*l.* a year, and the filtering for 94,000,000 a day would be 20,000*l.* a year, making a total of 128,000*l.* a year for pumping and filtration. Then I have done this in order to be surer still. I have analyzed the average height of the lift of each of the companies with the quantity of water which they lift, and I find that it comes to 200 feet as nearly as possible the average lift, and that the horse power required for lifting that quantity constantly at work, namely, 95,000,000 gallons, which is the quantity that they have taken for the year 1866, is 4,000 horse power, and I have supposed that they will be all as good engines as the East London Company's; therefore allowing for the intermittent supply, the greater cost of keeping the different engines at work, in order to supply the various quantities in the course of the day, I have taken it in round numbers at 20*l.* per horse power, that is 80,000*l.* a year. Then I have added 2*l.* a year for wear and tear and renewals on the horse power actually in use, (not the whole horse power employed, but that which is actually in use to produce that result,) that is 8,000*l.* a year, and the filtering I have taken at 23,000*l.*, and that comes altogether to 111,000*l.* But two large companies do not do their filtering at that rate, it costs them beyond the allowance of 23,000*l.* an extra amount of 8,500*l.*, and adding that it comes to 119,500*l.* a year in round numbers. Therefore from those various data, which I have been obliged to work out in the best way I could, I have taken the actual working expenses of pumping and filtering at 120,000*l.* a year. I have been rather careful to give you the grounds on which I have arrived at this, because when that is capitalized at 25 years' purchase, as I shall have to capitalize it as representing money borrowed at 4 per cent., it is important that I should be quite right upon those figures. I have tried to obtain direct information, but have not been able to do so. Then I have esti-

mated as nearly as possible the cost to which the companies must be subject for getting an additional 35,000,000 gallons a day. Taking the New River first from the paper before his Grace, they require 5,600,000 gallons in order to make up the quantity which I assume will be required when 130,000,000 gallons in the whole is required. It requires 600 horse power first of all to do the work, and I know by experience that you cannot put down pumping engines with pumps and buildings and all the other et cæteras, and everything complete, for less than 100*l.* per horse power, that is 60,000*l.* The expense of filters, reservoirs, and land for 6,000,000 gallons a day would be 4,000*l.* per 1,000,000 gallons, and there again I must give you the ground of my calculation. I have taken out the cost of filters which I myself have constructed in various parts of the country, and I happen to know also the cost at which filters are constructed on a large scale for the waterworks of London, and I find that allowing for the amount of filters which must always be out of use for cleansing, and the extent of filters which must also be at work in order to meet the varying quantities, not only of the months of the year but of the days of the month, a low estimate for the cost of construction would be 3,000*l.* per 1,000,000 gallons upon the quantity of water actually filtered, and then I have to add 20 per cent. for irregularity, which comes to 600*l.*, and for the land about three quarters of an acre for each 1,000,000 gallons, which I put at 400*l.*, which it would be where you are pretty near towns, it may be more or less than that, but that makes a total of 4,000*l.* per 1,000,000 gallons. My own filters at Chester, for instance, cost 3,485*l.*; at Dumfries, where I took the actual basins of an old filter, and supplied them with new filtering media, the cost of doing that was 2,240*l.* per 1,000,000 gallons, and at Rathmines, near Dublin, including a receiving tank, it was 6,600*l.* per 1,000,000 gallons. I could give many other instances, but I believe I am right in taking on the average, including all attendant expenses belonging to the construction of filters, 4,000*l.* per 1,000,000 gallons. I must now draw the attention of the Commission also to another thing before you can see clearly how we have to estimate the cost of pumping. The water companies make a return to the registrar general, and in various other ways they give information, but they return to the registrar general a monthly account of the average daily quantity used in each month; and if the Commission will allow me I will hand in the following tables:—

TABLE showing the average daily Quantity of Water supplied by the London Water Companies during the years 1866 and 1867, and during the summer months of June, July, August, and September in each year. Compiled from the Returns made to the Registrar General.

Name of Company.	Average daily supply for year		Average daily supply for the summer months of June, July, August, and September.	
	1866.	1867.	1866.	1867.
	Gallons.	Gallons.	Gallons.	Gallons.
Chelsea	7,918,375	8,087,258	8,390,550	8,825,125
West Middlesex	8,236,878	8,816,486	8,894,328	9,443,872
Southwark and Vauxhall	12,679,311	13,629,758	12,902,433	13,970,687
Grand Junction	8,709,089	9,533,432	9,367,220	10,511,205
Lambeth	8,950,566	8,975,533	9,691,775	9,680,825
Total from River Thames	46,494,219	49,042,467	49,246,306	52,431,714
New River	22,931,917	23,790,667	24,636,500	25,927,750
East London	19,321,989	19,298,241	20,702,466	20,094,035
Kent	6,148,562	6,468,873	6,684,885	7,027,292
Total from other sources	48,402,468	49,557,781	52,023,851	53,049,077
Total from all sources	94,896,687	98,600,248	101,270,157	105,480,791
Increase in average daily supply in 1867 over 1866	—	3,703,561	—	4,210,644

TABLE showing the average daily Quantity of Water supplied by the several London Water Companies during each month of 1866. Compiled from the Returns made to the Registrar General.

Months.	From the River Thames.					From other Sources.			Totals.
	Chelsea.	West Middlesex.	Southwark and Vauxhall.	Grand Junction.	Lambeth.	New River.	East London.	Kent.	
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
January	7,658,800	7,657,423	12,125,000	8,067,112	7,620,200	22,330,000	17,592,000	5,376,676	88,427,211
February	7,207,500	7,503,685	12,165,000	8,029,682	8,248,600	21,422,000	17,366,000	5,118,749	87,061,216
March	7,608,900	7,515,046	12,152,000	8,002,300	7,850,500	21,228,000	17,786,000	5,373,894	87,516,640
April	7,490,300	7,807,567	12,170,000	8,246,186	8,571,300	21,301,000	17,945,000	5,974,100	89,505,453
May	7,385,800	8,397,709	12,175,000	8,855,725	8,904,800	23,092,000	18,357,000	6,025,420	93,193,454
June	8,393,700	8,742,130	12,175,000	9,367,654	9,219,500	23,232,000	19,000,000	6,282,400	96,412,384
July	8,671,600	9,090,414	12,180,000	9,800,484	9,907,400	25,812,000	20,524,885	6,791,427	102,778,210
August	8,284,100	9,000,331	13,653,732	9,439,733	9,884,600	25,579,000	22,558,000	6,835,483	105,234,979
September	8,212,800	8,744,436	13,601,000	8,861,011	9,755,600	23,923,000	20,726,981	6,830,229	100,655,057
October	8,259,900	8,458,552	13,369,100	8,804,724	9,540,100	22,828,000	20,481,000	6,521,529	98,262,905
November	8,060,900	8,052,535	13,255,400	8,384,310	9,085,100	22,815,000	19,685,000	6,503,833	95,842,078
December	7,786,200	7,872,706	13,130,500	8,650,150	8,819,100	21,621,000	19,842,000	6,149,006	93,870,662
Average	7,918,375	8,236,878	12,679,311	8,709,089	8,950,566	22,931,917	19,321,989	6,148,562	94,896,687
Average of June, July, August, and September	8,390,550	8,894,328	12,902,433	9,367,220	9,691,775	24,636,500	20,702,466	6,684,885	101,270,157

TABLE showing average daily Quantity of Water supplied by the several London Water Companies during each month of 1867. Compiled from the Returns made to the Registrar General.

Month.	From the River Thames.					From other Sources.			Total.
	Chelsea.	West Middlesex.	Southwark and Vauxhall.	Grand Junction.	Lambeth.	New River.	East London.	Kent.	
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
January	7,060,300	8,195,541	13,100,000	8,726,626	8,678,000	22,339,000	19,924,000	6,080,750	94,104,217
February	7,912,200	8,666,760	13,100,000	8,845,640	8,090,000	22,206,000	19,975,000	6,250,462	95,136,062
March	7,499,400	8,374,912	13,100,000	8,624,220	8,374,600	21,121,000	18,942,000	6,083,776	92,121,908
April	7,884,900	8,667,501	13,200,000	9,003,981	8,696,000	21,947,000	18,563,000	6,149,625	94,106,007
May	8,360,200	9,228,482	13,225,000	9,920,108	9,250,700	24,772,000	19,207,000	5,901,849	99,865,339
June	8,814,600	9,776,707	13,950,000	10,435,045	9,679,700	26,326,000	20,060,000	7,179,286	106,221,338
July	9,042,800	9,750,965	13,975,000	11,032,742	10,257,800	26,710,000	20,321,152	7,156,708	108,287,167
August	8,875,400	9,326,213	13,978,000	10,409,492	9,592,200	25,617,000	20,192,986	7,039,261	105,030,552
September	8,567,700	8,921,602	13,979,750	10,167,542	9,193,500	25,058,000	19,802,000	6,683,913	102,384,107
October	7,875,200	8,685,121	13,981,340	9,387,510	8,641,500	22,474,000	18,948,657	6,600,000	96,593,328
November	7,560,800	8,230,377	13,983,260	8,953,523	8,937,500	23,532,000	17,983,600	6,112,074	95,293,134
December	7,593,600	7,973,648	13,984,740	8,894,756	8,314,800	23,296,000	17,659,500	6,342,773	94,059,817
Average	8,087,258	8,816,486	13,629,758	9,535,432	8,975,533	23,790,667	19,298,241	6,468,873	98,600,248
Average of July, August, and September	8,825,125	9,443,872	13,970,687	10,511,205	9,680,825	25,927,750	20,094,035	7,027,292	105,480,791

J. F. Bateman, Esq.

5 March 1868.

From the first of these tables you will see the average daily quantity. The average quantity consumed in 1866 you will find was 95,000,000 gallons in round numbers, and in 1867, 98,600,000 gallons. In the summer months, June, July, August, and September, when the largest quantity was delivered, the average daily quantity was 101,270,157 gallons in 1866, and 105,480,791 in 1867, showing that the increase of 1867 over 1866 upon the average quantity of the year was 3,703,000 gallons per day, and in the four summer months, June, July, August, and September, it was 4,210,000 gallons a day of increase. If you will have the goodness to turn to the two latter tables you will see the monthly variation. In January, February, March, and April 1866, it varied from 88,427,211 gallons to 89,505,453 gallons per day on the average of those months. In July it rose to 102,778,210 gallons, in August to 105,234,979 gallons, and in September to 100,655,057, so that you will see that the variation is from 88,000,000 to 105,000,000 in round numbers, which is as nearly as possible 20 per cent. or 10 per cent. upon 95,000,000, which was the average of the whole year. You must therefore have engine power sufficient to provide not for the 95,000,000, but for 10 per cent. more than that, or else you will be short of engine power when your greatest demand comes. That, however, shows only the monthly variation, and you have also not only to provide engine power for an average supply of 105,000,000 odd, but you must have engine power for supplying the diurnal variation during the 30 days of the month. The consumption on the maximum day of the month will be very much more than the average of the month, and you must at least add 20 per cent. more for that, for the additional days in some of the months, so that you have to provide for the maximum monthly quantity, and for 20 per cent. more than that, in order to meet the day of greatest demand, and you have to take this all into consideration in determining the quantity of horse power which is to be put down.

I will now hand in tables showing the cost of procuring additional supplies from the Thames. (*See Appendix M* (2)).

THAMES SUPPLY.—1st Instalment.

Estimated outlay for works, and annual working expenses, capitalized at 25 years' purchase, for obtaining an additional 35,000,000 gallons daily from the Thames, making a total supply of 130,000,000 gallons daily.

The additional supply will probably be required by the several companies in the proportions given in the following Table:—

Name of Company.	Present Supply, 1866.	Additional Supply.	Total Supply.
	Gallons.	Gallons.	Gallons.
New River - -	23,000,000	5,600,000	28,600,000
East London -	19,300,000	7,300,000	26,600,000
Chelsea - -	8,000,000	1,150,000	9,150,000
Grand Junction -	8,250,000	4,350,000	12,600,000
West Middlesex -	8,700,000	4,600,000	13,300,000
Southwark and Vauxhall -	12,700,000	6,700,000	19,400,000
Lambeth - -	9,000,000	2,250,000	11,250,000
Kent - - -	6,050,000	3,050,000	9,100,000
Total - -	95,000,000	35,000,000	130,000,000

SUMMARY OF COST.

Company.	Additional Quantity of Water required.	Estimated Outlay in Works.	Estimated annual working Expenses.	Working Expenses capitalized at 25 years' purchase.	Total Cost, including annual working Expenses capitalized.
	Gallons.	£	£ s. d.	£	£
New River -	5,600,000	242,025	9,014 3 7	225,350	467,375
East London -	7,300,000	247,000	9,065 16 0	226,650	473,650
Chelsea - -	1,150,000	16,500	1,622 19 6	40,575	57,075
Grand Junction	4,600,000	160,165	9,175 11 1	229,375	389,540
West Middlesex	4,350,000	118,530	7,528 15 7	188,225	306,755
Southwark and Vauxhall -	6,700,000	224,411	9,068 15 5	226,725	451,136
Lambeth	2,250,000	126,750	2,796 12 0	69,900	196,650
Kent -	3,050,000	159,020	3,790 15 9	94,775	253,795
Totals -	35,000,000	1,294,401	52,063 8 11	1,301,575	2,595,976

Annual working expenses of present (1866) supply of 95,000,000 gallons daily:—

Pumping and filtration - -	£120,000	
Payments to Thames Conservancy by five companies now drawing from Thames -	6,400	
New River Company, Payment to Lea Trustees - - -	£1,500	
Hertford sewage -	600	
	2,100	
East London Co., Payment to Lea Trustees - - -	2,000	
Present annual cost -	£130,500	Capitalized at 25 years = 3,262,500
Total cost of increasing supply from Thames to 130,000,000 gallons daily - - - - -		£5,858,476

THAMES SUPPLY.—2nd Instalment.

Estimated outlay for works, and annual working expenses, capitalized at 25 years' purchase, for obtaining a further additional supply of 40,000,000 gallons daily, increasing the supply to 170,000,000 gallons daily.

The additional supply will probably be required by the several companies in the proportions given in the following Table:—

Name of Company.	Present Supply, and first additional Supply as already apportioned.	Additional Supply now estimated for.	Total Supply.
	Gallons.	Gallons.	Gallons.
New River - -	28,600,000	8,580,000	37,180,000
East London -	26,600,000	7,980,000	34,580,000
Chelsea - -	9,150,000	2,835,000	11,985,000
Grand Junction -	13,300,000	3,990,000	17,290,000
West Middlesex -	12,600,000	3,780,000	16,380,000
Southwark and Vauxhall -	19,400,000	5,820,000	25,220,000
Lambeth - -	11,250,000	3,375,000	14,625,000
Kent - - -	9,100,000	3,640,000	12,740,000
Totals - -	130,000,000	40,000,000	170,000,000

SUMMARY OF COST.

Company.	Additional Quantity of Water required.	Estimated Outlay in Works.	Estimated annual working Expenses	Working Expenses capitalized at 25 years' purchase.	Total Cost, including annual working Expenses capitalized.
	Gallons.	£	£ s. d.	£	£
New River -	8,580,000	261,825	14,153 11 1	353,850	615,675
East London -	7,980,000	247,000	9,801 3 7	246,025	492,025
Chelsea - -	2,835,000	94,274	3,313 7 0	82,850	177,124
Grand Junction	3,990,000	178,394	5,372 14 2	134,325	312,719
West Middlesex	3,780,000	180,497	4,669 6 9	116,725	297,222
Southwark and Vauxhall -	5,820,000	174,900	12,420 10 6	310,500	485,400
Lambeth -	3,375,000	58,850	4,733 0 1	118,325	177,175
Kent - -	3,640,000	60,016	6,925 0 11	173,125	233 141
Totals -	40,000,000	1,255,756	61,388 14 1	1,534,725	2,790,481

Approximate estimate of cost of storage reservoirs on the Thames, to be constructed before more than an average quantity of 154,000,000 gallons per day can be obtained -	1,500,000
	£4,290,481
Amount of outlay in works and annual working expenses capitalized of first instalment, and present annual working expenses capitalized.—See summary at end of estimate of first instalment - - - - - - - -	5,858,476
Total cost of increasing supply from Thames to 170,000,000 gallons daily - - - - - - - - -	£10,148,957

THAMES SUPPLY.—3rd Instalment.

Estimated outlay for works, and annual working expenses, capitalized at 25 years' purchase, for obtaining a further additional supply of 30,000,000 gallons daily, increasing the supply to 200,000,000 gallons daily.

The additional supply will probably be required by the several companies in the proportions given in the following Table :—

Name of Company.	Present Supply, and first and second additional Supplies as already apportioned.	Additional Supply now estimated for.	Total Supply
	Gallons.	Gallons.	Gallons.
New River	37,180,000	6,500,000	43,680,000
East London	34,580,000	6,000,000	40,580,000
Chelsea	11,985,000	1,500,000	13,485,000
Grand Junction	17,290,000	3,000,000	20,290,000
West Middlesex	16,380,000	3,000,000	19,380,000
Southwark and Vauxhall	25,220,000	4,000,000	29,220,000
Lambeth	14,625,000	2,500,000	17,125,000
Kent	12,740,000	3,500,000	16,240,000
Totals	170,000,000	30,000,000	200,000,000

SUMMARY OF COST.

Company.	Additional Quantity of Water required.	Estimated Outlay in Works.	Estimated annual working Expenses.	Working Expenses capitalized at 25 years' purchase.	Total Cost, including annual working Expenses capitalized.
	Gallons.	£	£ s. d.	£	£
New River	6,500,000	138,600	13,104 0 0	327,600	466,200
East London	6,000,000	108,900	10,240 0 0	256,000	364,900
Chelsea	1,500,000	23,100	1,776 0 0	44,400	67,500
Grand Junction	3,000,000	81,400	5,528 0 0	138,200	219,600
West Middlesex	3,000,000	92,950	4,709 0 0	117,725	210,675
Southwark and Vauxhall	4,000,000	85,800	6,555 0 0	163,875	249,675
Lambeth	2,500,000	66,000	5,054 0 0	126,350	192,350
Kent	3,500,000	150,000	2,688 0 0	67,200	217,200
Totals	30,000,000	746,750	49,654 0 0	1,241,350	1,988,100

Amount of outlay in works and annual working expenses capitalized of first and second instalments, present annual working expenses capitalized, and cost of storage reservoirs on the Thames.—See summaries at end of estimates of first and second additional instalments - - 10,148,957

Total cost of increasing the supply from the Thames to 200,000,000 gallons - - - - - - £12,137,570

THAMES SUPPLY.—4th Instalment.

Estimated outlay in works, and annual working expenses, capitalized at 25 years' purchase, for obtaining a further additional supply of 30,000,000 gallons daily, increasing the supply to 230,000,000 gallons daily.

The additional supply will probably be required by the several companies in the proportions given in the following Table :—

Name of Company.	Present Supply, and first, second, and third additional Supplies, as already apportioned.	Additional Supply now estimated for.	Total Supply.
	Gallons.	Gallons.	Gallons.
New River	43,680,000	6,500,000	50,180,000
East London	40,580,000	6,000,000	46,580,000
Chelsea	13,485,000	1,500,000	14,985,000
Grand Junction	20,290,000	3,000,000	23,290,000
West Middlesex	19,380,000	3,000,000	22,380,000
Southwark and Vauxhall	29,220,000	4,500,000	33,720,000
Lambeth	17,125,000	2,500,000	19,625,000
Kent	16,240,000	3,000,000	19,240,000
Totals	200,000,000	30,000,000	230,000,000

SUMMARY OF COST.

Company.	Additional Quantity of Water required.	Estimated Outlay in Works.	Estimated annual working Expenses.	Working Expenses capitalized at 25 years' purchase.	Total Cost, including annual working Expenses capitalized.
	Gallons.	£	£ s. d.	£	£
New River	6,500,000	253,575	8,465 0 0	211,625	465,200
East London	6,000,000	212,400	5,349 0 0	133,725	346,125
Chelsea	1,500,000	36,850	1,830 0 0	45,750	82,600
Grand Junction	3,000,000	90,200	6,739 0 0	169,725	259,925
West Middlesex	3,000,000	101,200	6,942 0 0	173,550	274,750
Southwark and Vauxhall	4,500,000	192,732	3,956 0 0	98,900	291,632
Lambeth	2,500,000	101,450	2,337 0 0	58,425	159,875
Kent	3,000,000	51,150	4,694 0 0	117,350	168,500
Totals	30,000,000	1,039,557	40,362 0 0	1,009,050	2,048,607

Amount of outlay in works and annual working expenses capitalized of first, second, and third instalments, present annual working expenses capitalized, and cost of storage reservoirs on the Thames, see summaries at end of estimate of first, second, and third instalments - - 12,137,057

Total cost of increasing the supply from the Thames to 230,000,000 gallons per day - - - - - £14,185,664

THAMES SUPPLY.—SUMMARY of ESTIMATES for increasing the Supply from the Thames.

Quantity of Water. Gallons per Day on Average of Year.	Outlay in Works.	Annual Working Expenses.	Working Expenses capitalized.	Total Cost of additional Supply.	Total Cost of whole Supply.
	£	Estimated at £	£	£	£
Present (1866) supply 95,000,000 gallons	—	130,500	3,262,500	—	3,262,500
130,000,000 gallons, or additional supply of 35,000,000 gallons	1,294,401	52,063	1,301,575	2,595,976	5,858,476
170,000,000 gallons, or further additional supply of 40,000,000 gallons	1,255,756 and 1,500,000 (store reservoirs.)	61,389	1,534,725	4,290,481	10,148,957
200,000,000 gallons, or further additional supply of 30,000,000 gallons	745,750	49,654	1,241,350	1,988,100	12,137,057
230,000,000 gallons, or further additional supply of 30,000,000 gallons	1,039,557	40,362	1,009,050	2,048,607	14,185,664
300,000,000 gallons, or further additional supply of 70,000,000 gallons, at same rate of cost as for preceding instalments, including additional store reservoirs	3,026,314	105,502	2,637,550	5,663,864	19,849,528

Without going through the whole detail of these tables, but taking the sizes of pipes according to the quantity required and the distances, supposing that the New River Company, for instance, which has not yet gone to the Thames, went to Sunbury, which is a spot just above Hampton, and which was the spot selected by the East London Company last year, and which would be the most convenient place for the New River Company to go to, I make the actual cost in outlay 242,000*l.* for the New River Company. Then as regards the annual working expenses, I have taken the average quantity of water lifted 270 feet, (which is the amount, including friction,) at 21*s.* per 1,000,000 gallons. I have taken the wear and tear of the horse

J. F. Bateman, Esq.

5 March 1868.

power actually in use at 2*l.* per horse power per annum, and the filtering at one-sixth of a penny per 1,000 gallons, and that makes 8,014*l.* as the annual working expenses. You must then add 1,000*l.*, which the New River Company will have to pay to the Thames Conservancy Board, as the amount which they would have to contribute, which was the price fixed for the East London Company last year, and it is the price which was paid in addition to the sum formerly paid by each of the other five companies. The East London Company was to pay 1,000*l.*, and I put down 1,000*l.* for the New River Company, that makes a total of 9,014*l.* I have capitalised that at 25 years' purchase, which represents money borrowed at 4 per cent., and that comes to 225,000*l.*, being a total of outlay and of annual expenses capitalised of 467,000*l.* I have worked out the outlay of the East London Company in the same way, and of the Chelsea Water Company, and all the others, and I find that the gross cost which will be incurred in outlay will be 1,294,401*l.*, and the working expenses, capitalised at 25 years' purchase, will be 1,301,575*l.*, making a total cost, including the annual working expenses capitalised, of 2,595,976*l.* Then I have to add the present working expenses as nearly as I can ascertain them. I have taken, for reasons which I have already explained, the pumping and filtration at 120,000*l.* a year; the payments to the Thames Conservaney by the five companies now drawing water from the Thames 6,400*l.* a year; the payment by the New River Company, 1,500*l.* to the Lea trustees, and the expenses of the Hertford sewage clarification, which is 600*l.* a year at least, making 2,100*l.*, and the payment to the Lea trustees by the East London Company 2,000*l.*, making the total annual expenses 130,500*l.*, which capitalised at 25 years' purchase comes to 3,262,500*l.*, showing a total of 5,858,476*l.*

6607. Will the water companies get relief from those payments which they are now liable to make to the Conservators of the Thames if they cease to take water?—I should think so.

6608. Are you not aware that upon the strength of that money the Conservancy Board are laying out a considerable amount of money upon the Thames?—I cannot answer that question, but I should think they would be doing so. It is paid in consideration of certain duties performed by the Conservators for the purpose of keeping the river pure.

6609. (*Sir J. Thwaites.*) But they are performing those duties, are they not?—Yes, but they are annual expenses, and the payment is in consideration of their annual expenditure for what they call scavenging the river, and as they will no longer have occasion to scavenge the river the expenses will not be incurred, and there will be no occasion to pay.

6610. (*Col. Harness.*) Are the Conservators borrowing money upon the strength of that payment?—I cannot answer that question, but they will not have borrowed as much as represents a payment of 6,200*l.* a year, or else they would have nothing left out of the annual payment if the whole was absorbed in interest to do the scavenging of the river with.

I have then considered that the Kent water, judging from the report of Dr. Frankland, is certainly not a desirable water to deliver to the inhabitants, and therefore I have supposed that the additional quantity of water which the Kent Company may require shall also be taken from the Thames, which is, in every way, by analysis, a superior water. The total cost, treated in this way, of obtaining 130,000,000 gallons in the whole from the Thames and the other existing sources, including the Kent supply as far as it now goes, is 5,858,476*l.* The cost of obtaining the same quantity of water from North Wales is 6,602,188*l.*, being a difference of 743,712*l.* against the Welsh scheme in money expenditure, exclusive of interest and other expenses during construction. If these be added the difference against the Welsh scheme (if no charges of the same kind be made against the Thames) will be 1,826,530*l.* When a total quantity of 170,000,000 gallons per day is required it will be nearly 600,000*l.* in favour of Wales, vide table, p. 389 of Evidence given 11th March 1868, Q. 6632. It therefore appears that at present, and for some years to come, it is cheaper to get a supply from the Thames and from the existing sources than from a distance. But a period will arrive at no great distance of time, say in something like 10 years from the present time, when, looking at it as a mere question of cost in pounds, shillings, and pence, it will be cheaper to bring it from Wales than it will to take it from the Thames. That is a period of four years only, or five at most, later than the period at which the works will be completed; and as I observed yesterday, we must always be at least five years ahead of the actual demand, in consequence of the time which is required for executing works of extension; therefore in seven or eight or ten years at most, looking forward to the works with which you must be always in advance, it will be a tie between Wales and the Thames, and if so, it is a tie between water of only one or two degrees of hardness, and water of 13 or 14 degrees of hardness, a difference which will certainly save to the inhabitants of London a sum equal to about 500,000*l.* a year, which is the representative of about twelve millions of money at 4 per cent.; on these figures it surely would be worth while going to that extra distance for the water. I must observe that in the estimate of the amount of money to be expended upon the Thames for supplying 170,000,000 gallons, I have added a sum for the cost of constructing reservoirs upon the Thames. Those have not been carefully estimated, but they have been guessed at by witnesses before you at about 800,000*l.* for reservoirs alone, to which is to be added a tunnel to Abingdon, and many other things, so that is an under-estimate of the whole cost. I have allowed for the whole expenditure which may be required 1,500,000*l.*; it may be 200,000*l.* or 300,000*l.* more or less. I have not gone particularly into it.

The scheme which I have laid before you is based upon a quantity of 230,000,000 gallons; if it were prepared for 300,000,000 gallons certain parts of the work would have to be enlarged. The district itself which is appropriated, without taking in any other districts which may be added to the scheme, will give 300,000,000 gallons if it is measured by 120 days of drought; but in order to convey 300,000,000 gallons those portions of the conduit which will be covered must be made rather larger, and in arranging the level at which the open conduit must be constructed it must be so adjusted that in passing under railways or roads it shall be sufficiently depressed to allow the addition of some couple of feet to the side walls, according to the sketch which I will show you (*producing a sketch and explaining the same*). Instead of 16 feet 6 inches, which I believe is the width of the covered conduit for the conveyance of 230,000,000 gallons, the conduit will have to be made 18 feet wide and 2 feet deeper, and the open conduit will have to be arranged with a view to raising the side walls, by the parts coloured purple, whenever the additional quantity is required. A 10 feet deep conduit, according to the shape which has been prepared, will convey 230,000,000 gallons, and with 2 feet added it will convey 300,000,000 gallons; that is the whole additional work as far as the open conduit is concerned, and the covered conduit, instead of being 16 feet 6 inches, will have to be made 18 inches wider than it would be for the conveyance of 230,000,000 gallons, and 2 feet deeper. An additional reservoir will have to be constructed for holding the increased quantity of water at Edgware, and additional syphons will have to be constructed. All that is required in the first instance is the enlargement of the covered portion of the conduit, and for that the additional cost is only 225,000*l.*

6611. What would it have cost if it had been made the full size originally?—225,000*l.* I am supposing now that you contemplate making it large enough for 300,000,000 gallons. The open watercourse does not require to be altered at all, when the time comes you

add a little bit at each side. Then the covered conduit would be required to be made of larger dimensions, and the difference between the cost of making it of dimensions sufficient for passing 230,000,000 gallons, and of dimensions sufficient to pass 300,000,000 gallons, with the same fall per mile, would be 225,000*l.*, to which there is 15 per cent. to be added, making as nearly as possible 250,000*l.* I will now hand in my estimate for the additional outlay for the supply of 300,000,000 gallons.

J. F. Bateman, Esq.

5 March 1868.

WELSH SCHEME.

Estimate of additional outlay if works laid out for a supply of 300,000,000 gallons per day instead of 230,000,000 gallons.

Main aqueduct from Marten Mere to Edgware.		
Covered aqueduct or tunnel (for particulars and estimate, see Appendix A R (1)) - -	£36,800	
Estimate for 230,000,000 gallons - - - - -	33,180	
Difference per mile -	£3,620	
Length 65 miles, at 3,620*l.* - - -		£225,300
Open aqueduct (for particulars and estimate, see Appendix A R (2))	£27,640	
Estimate for 230,000,000 gallons - - - - -	25,000	
Difference per mile -	£2,640	
Length 75½ miles, at 2,640*l.* - - -		199,320
		£424,620
Contingencies, 15 per cent. - - -		63,693
		£488,313
Syphons:		
Three additional lines of 4 feet pipes, 10,824*l.* × 3 = 32,472*l.* per mile.		
11½ miles, at 32,472*l.* =	£373,428	
River crossings, valves, &c. -	7,500	
	£380,928	
Contingencies, 5 per cent. -	19,046	
		399,974
		£888,287
Additional land, say - - - -		11,713
Branch aqueducts to join main aqueduct at Marten Mere:		
Branch aqueduct from Vyrnwy and Banw district as proposed will discharge 150,000,000 gallons daily if required by a little additional depth of water.		
Amount carried forward - - -		£900,000
Amount brought forward - - -		£900,000
Additional syphon pipes, 1 line:		
2 miles at 10,824*l.* per mile - -	£21,648	
River crossing, valves, &c. -	2,500	
	£24,148	
Contingencies, 5 per cent. - -	1,207	
	£25,355	
Branch aqueduct from Severn district to Marten Mere:		
Same section as proposed for Vyrnwy and Banw branch aqueduct would have to be adopted.		
Cost for open watercourse, per mile -	£20,100	
Cost of section estimated for - -	14,820	
Difference per mile	£5,280	
14½ miles, at 5,280*l.* -	76,560	
Cost of covered watercourse or tunnel, per mile -	£26,100	
Cost of section estimated for - -	24,000	
Difference per mile	£2,100	
7 miles, at 2,100*l.* -	14,700	
	£116,615	
Contingencies, 15 per cent. -	17,492	
		134,107
Additional reservoirs and works for collecting and storing water, say - -		150,000
		£1,184,107
Say £1,200,000		

6612. (*Mr. Harrison.*) Do you propose to make your covered conduit the full size in the first instance?—I think 230,000,000 gallons is a tolerable quantity, but I think it would be advisable to make it the full size for 300,000,000 gallons.

6613. Supposing you had to alter this covered conduit, how would you do that with the supply going on?—That would be a difficulty of course; probably you would have to make another conduit, and it would be better to have it made the full size in the first instance.

6614. As far as your covered conduit was concerned you could hardly alter it?—No, we should be obliged to make another.

6615. Assuming that ultimately you may have to supply the larger quantity, would it not be as well either to make the conduit of the full size in the first instance, or to make two culverts, one merely equal to 170,000,000 gallons in the first place, and afterwards to make a second one for the remaining quantity whenever it may be required?—Possibly the latter. They are very large things when they come to be 18 feet wide, but it would be much more costly.

With reference to a question which was asked me yesterday, as to what the rainfall of a minimum year was as compared with the mean rainfall, perhaps I may be allowed to put in the following statement. I have extracted from the Liverpool returns, which represent seven gauges and 14 years' observations, and from the Glasgow returns, which represent a good many years' observations, and from the Manchester waterworks returns, the proportion which a minimum year bears to the mean rainfall. That is perhaps rather important, and I will hand it in.

The witness delivered in the following table:

TABLE showing the minimum Rainfall at various Places, and the Proportion which it bears to the mean Rainfall of those Stations.

Stations.	No. of Years' Observations.	Minimum Rainfall.	Mean Rainfall.	Proportion of Minimum to mean Rainfall.
Liverpool, C.W.W.—Rivington.	14	34·78	45·14	77 per cent.
Glasgow, C.W.W.—Loch Katrine district.				
Bridge of Turk - -	14	39·00	59·2	66 „
Glen Finlas - - -	11	48·00	59·2	81 „
Glengyle - - -	14	65·5	92·0	71 „
Aberfoyle - - -	14	34·6	53·9	64 „
Ledard - - -	12	67·1	85·0	79 „
Ben Lomond - -	13	67·2	90·6	74 „
Average of Loch Katrine district.	—	53·57	73·3	73 „
Manchester, C.W.W.—				
Rhodes Wood - -	12	34·49	44·20	78 „
Woodhead - - -	12	40·33	48·83	84 „

The witness withdrew.

Adjourned to Wednesday next, at 12 o'clock.

Wednesday, 11th March 1868.

PRESENT:

HIS GRACE THE DUKE OF RICHMOND, K.G., IN THE CHAIR.

Sir JOHN THWAITES.
Alderman Sir BENJAMIN PHILLIPS.
Colonel HARNESS, C.B.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

J. F. Bateman, Esq.

11 March 1868.

JOHN FREDERIC BATEMAN, Esq., further examined.

6616. (*Chairman.*) Will you kindly proceed with your evidence from the point at which you left off on Thursday last?—I wish to say a few words in further explanation of the evidence which I was giving just before I concluded on Thursday.

The following calculations will show the accumulating interest and expenses during the construction of works.

WELSH SUPPLY.

MEMORANDUM as to Interest on Outlay for Works during the time of their execution.

Time required from commencement of parliamentary proceedings to completion of works, as follows:

Preliminary investigation of country on line of aqueduct, surveys, sections, and Act of Parliament	1 year
Preparation of working drawings, arrangements for land, &c.	1 year
Execution of works from time of letting contracts to delivery of water to the existing centres of supply	5 years
	7 years

MEMORANDUM as to Time and Manner in which Outlay would be apportioned.

Reservoirs in Wales, and main and branch aqueducts would be in course of construction during the whole five years, and over this period the cost, estimated at 5,760,000*l.*, would be spread.

The service reservoirs at Edgware and aqueduct thence to Crouch End would be in course of construction during the last three years, and over this period the cost, estimated at 470,000*l.*, would also be spread.

The syphons on the branch and main aqueducts, and the pipes for connecting the scheme with the existing centres of supply, would be laid during the last two years, and over this period the estimated cost, 1,379,000, would also be spread. The total estimate for works, including land and contingencies, is in round numbers 7,600,000*l.*

Outlay:

1st year—Parliamentary plans and surveys, Act of Parliament, &c.		£50,000
2nd year—Preparation of contract drawings, arrangements for land, &c.		250,000
3rd year—$\frac{1}{5}$ of 5,760,000*l.* =	£1,152,000	
Superintendence	25,000	
		1,177,000
4th year—$\frac{1}{5}$ of 5,760,000*l.* =	1,152,000	
Superintendence	25,000	
		1,177,000
5th year—$\frac{1}{5}$ of 5,760,000*l.* =	1,152,000	
$\frac{1}{3}$ of 470,000*l.* = say	158,000	
Superintendence	28,000	
		1,338,000
6th year—$\frac{1}{5}$ of 5,760,000*l.* =	1,152,000	
$\frac{1}{3}$ of 470,000*l.* =	156,000	
$\frac{1}{2}$ of 1,370,000*l.* =	685,000	
Superintendence	40,000	
		2,033,000
7th year—$\frac{1}{5}$ of 5,760,000*l.* =	1,152,000	
$\frac{1}{3}$ of 470,000*l.* =	156,000	
$\frac{1}{2}$ of 1,370,000*l.* =	685,000	
Superintendence	40,000	
		2,033,000
		£8,058,000

Included in above for Act of Parliament, law, and engineering expenses, 458,000*l.* = 6 per cent. on 7,600,000*l.*

Interest at 4 per cent. per annum will be as follows:

Outlay of 1st year—	£50,000	Interest due at end of following year	£2,000
2nd year	250,000		
	50,000		
	2,000		
	302,000	Do.	12,080
3rd year	£302,000		
	12,080		
	1,177,000		
	1,491,080	Do.	59,643
4th year	£1,491,080		
	59,643		
	1,177,000		
	2,727,723	Do.	109,109
5th year	£2,727,723		
	109,109		
	1,338,000		
	4,174,832	Do.	166,993
6th year	£4,174,832		
	166,993		
	2,033,000		
	6,374,825	Do.	254,993
7th year, £2,033,000, half of which will bear interest and become due at end of year, 4 per cent. on say 1,000,000*l.* for half a year			20,000
Total amount of interest due and payable to end of 7th year, when works are to be finished and in a revenue producing condition			£624,818

WELSH SCHEME.

SUMMARY of Estimated Outlay for obtaining the Supply from Wales and distributing same to existing centres of supply, including interest of money and general expenses during construction of Works.

First instalment of 130,000,000 *gallons daily*—

Reservoirs and works for collecting and storing water in the Vyrnwy and Banw district, including land and contingencies	£489,882	
Branch aqueduct from river Banw to Marten Mere, including land and contingences	599,137	
		£1,089,019
Main aqueduct from Marten Mere to Service Reservoirs near Edgware (Syphon pipes—when required, capable of discharging 130,000,000 gallons daily)		5,453,359
Service reservoirs near Edgware, and distribution of water to the various districts		1,059,810
Cost of works		£7,602,188
General expenses, including Act of Parliament law and engineering expenses, 6 per cent. on 7,602,188*l.*	£458,000	
Interest on outlay during construction of works	624,818	
		1,082,818
		£8,685,006
Deduct value of property of companies which may be disposed of as soon as supply by gravitation is introduced		1,000,000
Total cost of obtaining first instalment of 130,000,000 gallons daily		£7,685,006
Amount carried forward		£7,685,006

Amount brought forward	-	£7,685,006
Second instalment of 40,000,000 *gallons daily additional—*		
Reservoirs and works for collecting and storing water in the river Severn proper district, including land and contingencies	£570,291	
Branch aqueduct to Marten Mere, including land and contingencies - - - - -	492,117	
Additional syphons on main aqueduct, from Marten Mere to Edgeware - - -	266,650	
Additional service reservoir near Edgeware, piping and other works for distribution of water to the various districts -	557,551	1,886,609
Total cost of obtaining a supply of 170,000,000 gallons daily - - - -		£9,571,615
Third instalment of 30,000,000 *gallons daily additional—*		
Additional syphons on main aqueduct from Marten Mere to Edgware - - - -	£133,324	
Additional mains and works for distribution of water - -	117,535	250,859
Total cost of obtaining a supply of 200,000,000 gallons daily - -		£9,822,474
Fourth instalment of 30,000,000 *gallons daily additional—*		
Additional syphons on main aqueduct from Marten Mere to Edgware - - - -	£133,324	
Additional service reservoir near Edgware, and works for distribution of water - -	444,225	577,549
Total cost of obtaining a supply of 230,000,000 gallons daily - - -		£10,400,023

In carrying out any new scheme it would probably require, even if one had the honour of starting the thing at once, and supposing there was no successful opposition, a year at least to prepare for and obtain an Act of Parliament; it would take at least another year to prepare the working drawings and specifications before the works could commence, and it would take five years to execute the works: that is seven years from the time at which any project could be seriously considered. Allowing for the previous time which might elapse, it would probably be eight or nine years from the present time before it could be considered possible that any scheme from a distant source could be brought into operation; but for the purpose of interest upon accumulating capital it would have to be taken from the time at which you commence the expenditure of money, and therefore beginning with a small amount of interest and with a gradually accumulating quantity as the money was being more rapidly spent, it would pass over a period of about seven years. I showed before the rate of progress at which the quantity of water demanded would probably proceed, and I fear I shall have to go over that a little to show you the probable period at which the water would be required, because upon that depends the comparison of the two outlays, for the purpose of showing at what period the cost of obtaining it by pumping from the Thames or from the Lea from the existing sources, and the cost of obtaining the quantity which will be required from Wales will be a tie, from which time of course gravitation works would be much cheaper than pumping works, and the comparison would be very much in favor of the Welsh scheme. At present the supply averages 32 gallons per head upon the gross population of the district supplied, measuring the number of the houses by the proportion of inhabitants to a house which obtains in the metropolitan districts. It so happens that the population measured in that way is just the amount of population within the metropolitan district commanded by the Board of Works, but a population of nearly 200,000 persons into whose houses the present companies carry their water, lies outside that metropolitan district; perhaps the whole of those are not supplied, but to whatever extent they are supplied, to that extent of course the population within the metropolitan board's jurisdiction are deficient in supply, and there is of course a very considerable number of people who have now no legitimate supply. The taking of water being voluntary, and the payment voluntary, there is no compulsion upon the people to take the water, and therefore there are many houses which are not legitimately supplied with water by the water companies. Allowing for that, and allowing for the great increase which it is alleged, and which it is feared by the existing companies will occur, as soon as a constant supply is given, (and I have no doubt it will increase, although probably by care it may be brought down to a proper legitimate amount in time, yet at first I have no doubt it will increase,) and taking into account also the high pressure which will be introduced and which will also increase the supply, I do not think it is safe to calculate upon less than 40 gallons a head. The 32 gallons now supplied are measured upon the gross population, and you would have to add to that amount the effect of constant supply which will increase the quantity, and you would have to add to that (if the works are carried out upon the principle of a commission being appointed and allowed to levy compulsory rates, and everybody therefore being in a condition to take the water,) the additional quantity which people now unsupplied with water would take, therefore I do not think it is safe to calculate upon less than 40 gallons a head if the system were carried out, as I think it ought to be carried out, of giving everybody a constant supply of water at high pressure.

J. F. Bateman, Esq.

11 March 1868.

6617. (*Sir J. Thwaites.*) Do you intend that quantity to include water used for manufacturing and other purposes?—Yes, it includes manufacturing purposes, public purposes, and everything else. The present population of London is about 3,100,000 persons—it has increased at the rate of 19 per cent. in the last 10 years—that is 1·9 per cent. per annum if it happened to be the average, but the average increase is 1·73 per cent. upon each year. Ten years hence, at the same rate of increase, the population would be rather more, but we will assume it at 3,700,000 persons. Ten years hence the average quantity of water, at 40 gallons per head per day, would be about 150,000,000 gallons daily, that is the average quantity. Then allowing 10 per cent. for the maximum variation above the mean, in the monthly means which are returned by the companies to the registrar general, the maximum quantity, or rather the average quantity of the summer months, because the summer months run very nearly the same, will be 165,000,000 gallons per day, that is within about 5,000,000 gallons per day of the maximum quantity which the companies have now the power of withdrawing from the Thames and from other sources. Perhaps I ought to allow them 180,000,000 for reasons which I will show afterwards, and in that case it would be within 15,000,000 gallons of the maximum quantity which the companies can now draw from the existing sources and from the Thames, allowing some addition which I will explain by and bye without the construction of storage reservoirs. At present the five Thames companies have the power of drawing each 20,000,000 gallons a day which makes 100,000,000. The East London company has acquired the power of drawing 10,000,000 gallons more, that would make 110,000,000 gallons, and if the New River and the Kent Companies were supposed to go to the Thames also they would probably get the power of drawing another 10,000,000 gallons which would make 120,000,000 gallons, and the East London and New River Company from their present sources, and the Kent from its present sources, the three combined

J. F. Bateman, Esq.

11 March 1868.

would draw about 50,000,000 gallons a day from other sources than the Thames, which makes a total of 170,000,000 gallons. Therefore if 170,000,000 gallons be considered as the maximum quantity, and that is the quantity which has been spoken to by various engineers who are interested in the Thames supply as the quantity which might be drawn from other sources before it was necessary to construct storage reservoirs upon the river Thames, one year more than 10, that is 11 years from the present time, would bring up the demand upon the Thames and upon the existing sources to the full extent to which they could obtain water without the construction of storage reservoirs. Then before they could take any further quantity they must have already constructed storage reservoirs.

6618. That is on the assumption, is it not, that no further quantity than the statutory limit could be taken without injuring the Thames?—I have allowed 120,000,000 gallons per day from the Thames before any reservoirs are needed.

6619. Is it your opinion that 120,000,000 gallons is the utmost that could be taken from the Thames without the storing process being resorted to?—I do not express any opinion upon that, because I have not specially considered the Thames, but I take the evidence which has been laid before the Commission, which is pretty much to this effect. Mr. Simpson, who is a very good authority upon that point, says that they can take 100,000,000 gallons, perhaps 120,000,000 gallons, and possibly 130,000,000 gallons from the Thames before storage reservoirs would be required, and that agrees with the evidence of other gentlemen which has been laid before the Commission; therefore I take that evidence in preference to expressing any opinion of my own upon that point. Then you will observe that if that is all they can take, or rather if that is the maximum quantity, the maximum quantity represents a greater quantity than the average, because they are not permitted by Act of Parliament to take on any one day more than a certain quantity, and the diurnal variation will probably be 20 per cent. greater than the average quantity throughout the year; therefore they must have constructed their storage reservoirs before they can get any quantity, say, more than 170,000,000 gallons, from all sources. The various estimates which have been given upon the cost of making those storage reservoirs entitle me to conclude that about a million and a half would be something like the cost of what it is considered would be required. Mr. Bailey Denton speaks of between 5,000,000*l.* and 6,000,000*l.* as being required for the purpose of purifying the water, and leaving the companies to pump the water as they do now. Mr. Beardmore speaks of 700,000*l.* or 800,000*l.* for the reservoirs, besides six miles of tunnel to Abingdon and other works which he does not estimate. I am endeavouring to estimate it as well as I can. I have allowed a million and a half upon the storage reservoirs and other works which would be required in the valley of the Thames, and that million and a half I have added to the expenditure required and the cost of pumping capitalized, in order to fix the cost at which any additional quantity beyond 130,000,000 gallons can be obtained. The expenditure which will be required by the water companies for obtaining 130,000,000 gallons a day is 5,858,476*l.*; that is to say, the additional cost in outlay, and the cost of working expenses, and the cost of raising 35,000,000 gallons more than their present supply, capitalized makes 5,858,476*l.*; and that is for 130,000,000 gallons on the average. Then before you can go beyond that quantity you have to add the expenditure for reservoirs which must be ready by the time you want them, and therefore it makes the total expenditure, before you can get more than 130,000,000 gallons, on the average 8,760,000*l.*

6620. What do you add for the reservoirs?—1,500,000*l.*; that is, the reservoirs, tunnels, land, and all the other works which would be necessary, and compensation, and every question connected with it. Before we can get 150,000,000 gallons, which would be the tie between Wales and the River Thames, we have to add 700,000*l.* upon works and 700,000*l.* which represents working expenses capitalized, making a total of 1,400,000*l.*, and those together bring up the figure to 8,760,000*l.*

6621. Do you mean working expenses plus that which is necessary for your scheme?—No, for obtaining 150,000,000 gallons from the Thames on the average of the year. You will have to expend first of all 5,858,476*l.* for bringing up the total supply to 130,000,000 gallons, then you have to expend 700,000*l.* in works for the further 20,000,000 gallons, and an additional amount of 700,000*l.* represents the working expenses, capitalizing the annual amount at 25 years. This makes a total of 1,400,000*l.* to be added to the expenditure upon reservoirs and other works of 1,500,000*l.*, making a total of 2,900,000*l.*, which, added to the other amount, makes a total of 8,760,000*l.* for 150,000,000 gallons a day.

6622. (*Sir B. Phillips.*) Is that in addition to the expenses already incurred?—That is in addition to all outlay already incurred; but that is capitalizing the present working expenses for the additional quantity, and estimating the cost to be incurred for obtaining the additional supply beyond what they are now supplying.

6623. You are assuming that in the next 10 years taking the average of 40 gallons of water per head, you will require 150,000,000 gallons for the use of the metropolis?—Yes.

6624. The present quantity is about 110,000,000 gallons, is it not?—In the summer months it is about that; it was about 95,000,000 gallons in 1866, on the average of the year, and 100,000,000 gallons last year.

6625. Then to produce that 150,000,000 gallons over the next 10 years, would the existing companies have to expend 8,760,000*l.*?—Yes, or an equivalent in working expenses. In addition to all their present outlay, after capitalizing the existing working expenses and the working expenses which will have to be incurred, and adding to that the outlay which will have to be incurred, it will cost them 8,760,000*l.*

6626. (*Sir J. Thwaites.*) Do I rightly understand that your contrast starts with the pumping expenditure of the existing companies?—Yes.

6627. And you hold in abeyance the mechanical arrangements for distribution in the metropolis apart from both schemes?—Yes.

6628. You take the cost of pumping at present which is in excess of that which you would require, because you bring your water to a level of 200 feet above high water?—270 feet.

6629. Therefore you would require less pumping?—Yes.

6630. Then you go on to calculate the cost of increasing the supply from the Thames and the increased pumping power necessary, and then you proceed still further to estimate the cost of forming reservoirs for the purposes of storing the floods?—Yes.

6631. And having continually to add the increased cost of pumping?—Yes.

6632. And the cost of the reservoirs with the different compensations, and every question of easement and so on, which brings up the cost on that side to 8,760,000*l.*?—That is so; that is merely the cost of an increased supply from the Thames. I have not yet gone into the question of obtaining it from Wales on the other side. I have now before me a table which I will hand in to the Commission, showing, on the basis which I have been explaining to the Commission the cost of obtaining from existing sources 130,000,000 gallons, 170,000,000 gallons, 200,000,000 gallons, 230,000,000 gallons, and 300,000,000 gallons a day, as contrasted with the cost of obtaining the same quantity from North Wales.

COMPARATIVE ESTIMATES of obtaining additional Supplies of Water from the existing Sources and from North Wales.

Quantity of Water per Day.	Cost from the Thames and existing Sources.	Cost from North Wales, including Interest, Superintendence, &c.	Difference in favour of	
			Existing Sources.	North Wales.
Gallons.	£	£	£	£
130,000,000	5,858,476	7,685,006	1,826,530	—
170,000,000	10,148,957	9,571,615	—	577,342
200,000,000	12,137,057	9,822,474	—	2,314,583
230,000,000	14,185,664	10,400,023	—	3,785,641

NOTE.—In the above estimate 1,000,000*l.* is deducted from the cost of the Welsh scheme as the value of the property of the companies to be released and disposed of on the introduction of a supply from Wales.

If a supply of 300,000,000 gallons daily be contemplated the comparison will be as follows:

From the Thames and existing sources -	£ 19,849,528
From North Wales - - -	11,600,023
Difference in favour of North Wales -	£ 8,249,505

The first quantity, 130,000,000 gallons would be obtained from the Thames for 5,858,476*l.*; the cost of obtaining that quantity from Wales, adding all the interest of the money which is to be expended and the working expenses during its construction and so on, would be 7,865,006*l.*, being a difference of 1,826,530*l.* in favour of the existing sources. That quantity of water will probably be required in something like seven or eight years from the present time, that is as soon as the new works from Wales could be executed, and before much additional quantity from Wales beyond 130,000,000 gallons could be supplied it would be necessary to construct the second branch of the Welsh works, which would give a large additional, in fact the full additional quantity of water with reference to the storage power and the full size of the conduits everywhere except where syphons were required. I have shown the Commission that before the water from the existing sources could get beyond that 150,000,000 or 160,000,000 gallons, the companies must have laid out 1,500,000*l.* in the valley of the Thames, so that when 170,000,000 gallons were required the state of the case would be this, that from the existing sources it would cost 10,149,000 in round numbers, and from Wales 9,571,000*l.* being a difference in favour of Wales at that time of 577,000*l.* and odd. That is at a period distant from the present time, probably about 12 or 13 years. The tie is in about 11 years, and when it comes to about 11 years from the present time, which would be only three or four years after the works could be possibly executed, it is as cheap to obtain water from Wales, if the whole scheme were laid out on the scale of 230,000,000 gallons, as it is to obtain water from the existing sources.

6633. (*Sir B. Phillips.*) Is 10,000,000*l.* your maximum calculation for bringing 170,000,000 gallons from Wales?—Yes, in round numbers, and including the conveying of that water to the higher service reservoirs of the existing companies, to produce the necessary connection with the existing systems.

6634. Would that 10,000,000*l.* include the interest of the unproductive capital during the time of making these works?—Yes, till the first instalment of water is supplied, not after that.

6635. You say that to supply 170,000,000 gallons of water to London, after all the calculation you have made, would cost about 10,149,000*l.*?—Yes.

6636. And consequently the question of cost as between the two is pretty near equal?—They are not far different. I have taken credit in the Welsh supply for 1,000,000*l.* sterling in respect of the pumps, engines, land, &e., which would be available for sale, and be no longer used or necessary for the pumping establishments, they being sold and yielding a million sterling.

6637. Then under all circumstances, looking at the extreme calculation of 40 gallons per head per diem in London, and the increased population within ten years, you have a balance in your favour of 20,000,000 gallons over and above what you think you will require for the absolute supply of London?—Yes. *J. F. Bateman, Esq.* 11 March 1868.

6638. You were first speaking of the cost of 130,000,000 gallons; you are now speaking of the cost of 170,000,000 gallons?—Yes. The tie between the one and the other would be in about 11 or 12 years; that would depend upon the increase in the quantity of water.

6639. As a set-off, do you propose to do anything with the extra 20,000,000, looking at it as a money question?—Yes; 20,000,000 gallons, if it could be sold on the way at as low a price as 3*d.* per 1,000 gallons, would be worth 90,000*l.* a year, which would represent something more than 2,000,000*l.* sterling. I might deduct that from that the cost of bringing it from Wales. I doubt whether in that time you would sell as much as 20,000,000 gallons, but I think it is very likely you would sell 10,000,000 gallons. Birmingham is within 10 miles of the line of conduit. Birmingham has at present a very bad and indifferent supply. There are 300,000 people in the Birmingham district who may be said to be indifferently supplied. Probably 200,000 of the whole population of the Birmingham and Wolverhampton district are well supplied at present, although they have to raise the water to a great height. As we pass Birmingham the conduit would be something like 370 or 380 feet above the level of the sea, and therefore very little short of the highest houses in Birmingham. I do not think that Birmingham can be higher than that, or very little higher than perhaps 400 feet. Therefore there would be no great height to lift the water, and no great distance to carry it, and 3*d.* per 1,000 gallons would be a very low price; and if 10,000,000 gallons were sold at Birmingham and other contiguous places, that would represent 45,000*l.* a year.

6640. (*Mr. Harrison.*) What would be the distance of the conduit from Birmingham?—10 miles.

6641. (*Sir B. Phillips.*) Could not you produce the 150,000,000 gallons at a proportionately lower cost?—A little lower cost. This estimate goes on the basis of an ultimate quantity of 230,000,000 gallons a day; and after the conduit is once made, it does for 230,000,000 gallons without any further expense connected with the conduit, with the exception of additional syphon pipes across the valleys from time to time, as they are required. Therefore nearly the whole cost of the ultimate supply is incurred in the first instance.

6642. Supposing your Welsh water to be a desirable supply for certain purposes to London, you would not propose to do away with the use of the Thames water entirely, would you?—Yes, entirely; you can get the Welsh water cheaper than the Thames water from the point at which the two tie. If you were to continue taking any part of the supply from the Thames, you would be keeping property tied up which might be disposed of, and you would be keeping up the expenses of pumping and filtering, and all the attendant expenses of working the existing system, which might be done away with.

6643. Do you think it would be desirable that a city like London, with 3,100,000 people, with a prospect of a very large increase in the next 10 years, should rely wholly and solely for its water upon a district 200 miles away?—I see no difficulty about it. I do not see that it would be impolitic. The other day I showed the position in which the service reservoirs at Stanmore might be constructed, and there you might make store reservoirs which would hold, as I have already estimated, two or three weeks supply, and I have also shown that the land there is so well situated that you may take almost any reasonable amount. You may get two or three months' supply for London independently of the reservoirs in Wales, at a distance of about 8½ miles from Hyde Park. I think that that is a safer supply for the

J. F. Bateman, Esq.

11 March 1868.

city of London in case of any difficulty than the Hampton or Thames Ditton pumping stations. It is nearer, it is more secure from difficulty and from danger, and there you have the water stored up almost within gunshot.

6644. Do you think, looking at it in the latter point of view, that the public would be quite as satisfied that they should be dependent entirely for a supply of water to a city like London upon water that they receive from a distance of 200 miles?—I do not think that the public would ever trouble their heads about it. If they got good water day by day they would never inquire where it came from. It is a matter for the Commission to consider rather than the public, for as to the policy I am sure they would not consider it. Glasgow gets its water from a place 35 miles off, Manchester from about 20 miles, Madrid from 40 or 50 miles, and Paris is going to take its water from 130 or 140 miles. Madrid and Paris are much more liable to have their conduits disturbed than we are, I hope, in this country.

The cost of 200,000,000 gallons from the existing sources would be 12,137,000*l.*, and from Wales 9,800,000*l.* in round numbers, being a difference in favour of Wales of 2,300,000*l.* Then 230,000,000 gallons would cost 14,200,000*l.* in round numbers from the existing sources, and 10,400,000*l.* from Wales, being a difference of 3,785,000*l.* in favour of Wales. I may observe that in all the above estimates 1,000,000*l.* is deducted in respect of the property of the existing companies which would be realized, and which might be sold after the first introduction of the water from Wales. If a supply of 300,000,000 gallons daily were to be contemplated, and the works were constructed with a view to that from the commencement, it would entail an additional cost of only about 500,000*l.* upon the whole undertaking, because the district for which the reservoirs were laid out would yield 300,000,000 gallons, and the conduit would only require in the covered parts to be made a little larger, and in the uncovered parts a little bit to be added to each side of the side walls, which would give you the full quantity, and additional syphon pipes. The contrast would then be that if 300,000,000 had to be taken from the existing sources, the outlay would be nearly 20,000,000*l.*, but if taken from North Wales 11,600,000*l.*, the difference upon that quantity in favour of Wales being 8,250,000*l.*

6645. You state, do you not, that the cost of 170,000,000 gallons in London from existing sources would be something like 10,149,000?—Yes.

6646. And the cost of 200,000,000 gallons would be 12,137,000*l.*, that is a difference of 2,000,000*l.*?—Yes.

6647. Will you state how it is that it should cost 2,000,000*l.* for the additional 30,000,000 gallons per day deliverable from the London supplies, and only 250,000*l.* for the same additional amount coming from Wales, because you say that the supply from Wales of 170,000,000 gallons cost 9,570,000*l.*, and the cost of the production of 200,000,000 from Wales is only 9,800,000*l.*, which makes only a difference of 250,000*l.* as between 170,000,000 and 200,000,000 gallons?—The difference is in the difference of the two systems. In bringing the water from Wales you have to construct your aqueduct upon a scale equal to the conveyance of the ultimate quantity of water that you are going to bring, therefore you have to make it a great deal larger than is necessary in the first instance, because it cannot be conveniently added to afterwards. After the reservoirs are once constructed and the branch aqueduct up to the northern district which would be equivalent to 150,000,000 gallons, the only additional cost which you would have to incur would be the construction of the reservoir in the green district on the map, and that branch to bring the water down to the main aqueduct, and additional syphon pipes across the rivers Severn and Stour which are the only rivers which you have to cross. The difference of cost is only 250,000*l.*, and I can give you the figures upon which those amounts are arrived at. You are taking 170,000,000 and 200,000,000 gallons deliverable from the Welsh source. The cost is simply this, that the whole works after you have got 150,000,000 or 170,000,000 gallons are then upon a scale capable of delivering 250,000,000 gallons with the exception of the syphon pipes across the intervening valleys, and the pipes to communicate betwen the service reservoirs near Edgware and the existing reservoirs of the existing companies. The cost of the syphon pipes across the valleys would be 133,000*l.*, and the cost of the additional mains and the additional service reservoirs to communicate with the existing district would be 117,000*l.*, 250,859*l.* altogether. In pumping that additional quantity from the Thames you have to get additional engines, and you have to lay down additional mains and to incur the annual cost of filtering and raising the water.

6648. In the construction of your project, would you recommend the production of the smaller or the larger quantity of water; would you say that we should be satisfied and that the machinery should be so constructed that 170,000,000 should be the maximum quantity, or that we should be able to take 300,000,000 gallons?—I certainly would not recommend you to take 170,000,000 gallons, but only you might fairly consider the propriety of taking the larger quantity, because comparing 300,000,000 gallons with 230,000,000 or 250,000,000 gallons, the 300,000,000 gallons would only cost you about 500,000*l.* more.

6949. But if we are to borrow the money, that at 4 per cent. would be equal to 20,000*l.* a year?—Yes.

6650. As you say that there might be some difficulty in getting rid for some considerable time of the additional 20,000 gallons a day which you propose by the smaller quantity, what should we do with the much larger quantity for many years to come?—That could not make it very expensive, because if you never sold more than one-half of what the 500,000*l.* would procure, it would be only 250,000*l.*, of which the interest would be about 10,000*l.* a year. If you look at the table you will notice that as to the 170,000,000 gallons, the cost is in favour of the Welsh scheme, and in 12 or 13 years it is in favour of the Welsh scheme if you do not sell any of the surplus quantity. If you sell the surplus quantity of water you can make more than the interest upon 300,000*l.* for the additional expenditure which might be required. But I think that is entirely a matter of policy. I think that 200,000,000 or 250,000,000 gallons would last you a very long time.

6651. (*Mr. Harrison.*) Your calculation is entirely based upon the assumption that 40 gallons per head will be necessary?—Yes, but that 40 gallons per head is taking only the population within the metropolitan district; there is a large surrounding district which is in fact rejected in that calculation.

6652. Supposing views have been expressed before this Commission by many of the leading engineers connected with waterworks in London, or I think by all of them, that 30 gallons per head, even with a constant supply, would be sufficient, then 300,000,000 gallons would be just equal to the requirements of 10,000,000 of population?—Yes.

6653. And of course if their views are right, that would require a deduction of just 25 per cent. in all your calculations?—Hardly that, because if you make it nett upon the requirements of the population in London, you would have no surplus to sell upon your way.

6654. Taking London alone, of course the difference between 30 and 40 gallons, which is 25 per cent. in the gross calculation, makes a very important item?—Yes, no doubt. They are now using more than 30 gallons, and I think there cannot be a doubt about the quantity increasing, if you only look at it as it ought to be looked at.

6655. I was taking the evidence given by gentlemen who have been before this Commission, that even under a constant supply, and under such supervision, by a water police, as they suppose would be adopted, the increase in consumption would be nil from that cause?—It never has been, and I am quite satisfied,

and they themselves admit it, that with the increased habits of cleanliness and luxury which have been introduced, and baths and waterclosets and so on, there will be a much larger supply of water required than there has hitherto been. Mr. Simpson himself admitted that he takes 30 gallons now, whereas he used to take 20 gallons only, and it has gone up to 50 gallons in Glasgow. No doubt it is wastefully used there, but in every case the consumption of water is regularly increasing, and if you take the past experience of London, and merely estimate the supply of water in future at the same rate as it has been going on, you will find that it increases about 3 per cent. per annum, much more rapidly than the population. The population increases at the rate of 1·73 per cent., and the consumption of water increases 3 per cent. per annum.

One other point I should like to observe upon before I go further, and that is the cost of raising 1,000,000 gallons. A letter was handed me on the last occasion from Mr. Quick, stating that his estimate was 13*s.* 10*d.* per 1,000,000 gallons raised 100 feet, but that, I think, does not include wages. It is so different from anybody else's estimate that I am quite sure there is something omitted.

6657. He says "I find the cost of raising 1,000 "gallons of water 100 feet high, is between one-sixth "and one-seventh of a penny, or 13*s.* 10*d.* per 1,000,000 "gallons, including coals, oil, tallow, wear and tear, "&c." The cost of raising it includes wages as a primary charge, and it does not follow that because he has not put it down specifically he has not included it?—I have here the returns made every year to the town clerk of London by the various water companies. The one I have before me is that of the Grand Junction Company, which is one of the companies of which Mr. Quick is engineer. Up to the year 1862 inclusive, there was this return, "Repairs of works and "premises, filter-bed charges, oil and other working "expenses," under one item, and there was a second item, "Directors, auditors, office, salaries and office "charges," that was the way in which the returns were made up for all the years from 1853 to 1862 inclusive. I will take the three or four last years. In 1859 the repairs of works and filter-bed charges and working expenses were 11,700*l.*, and another item, which did not include men's wages, was 5,400*l.* In 1861 the first item was 12,500*l.* odd, and the second item 5,500*l.* odd. In 1862 it was 11,700*l.* and 5,550*l.* In 1863 the return was made differently, and it was put "Repairs of works and premises;" it was the same as far as the first item was concerned, but the second item had added to it "and men's wages." Then the first item which evidently included men's wages before fell from 11,700*l.* in 1862, and 12,500*l.* in 1861, to 7,800*l.* in 1863, and 9,200*l.* in 1864; the second item which then included men's wages jumping up from 5,500*l.* to 10,200*l.* and 10,500*l.* If you take the last year, 1866, for the Grand Junction Company, under the item "Repairs of works and premises, filter-bed charges, coals, and other working expenses," the cost was 10,647*l.* Then if you deduct filtration, which Mr. Quick does at one-eighth of a penny, upon 1,000 gallons, that leaves 8,984*l.* That water has to be raised about 250 feet at the Grand Junction, and it comes to 22*s.* 6*d.* per 1,000,000 gallons raised 100 feet. There must be some mistake about that 13*s.* 10*d.* Now I will give the cost at various other places. In the old Manchester Waterworks at the Gorton pumping engine, which was a capital engine, made by the Hayle Foundry Company, but which was superseded when I brought the water from the hills, the cost of raising 1,000,000 gallons 100 feet was 31*s.* 7*d.* I know as a fact that in the East London Waterworks, where Mr. Greaves works very economically, it costs him 21*s.* 0½*d.* Mr. Hawskley, in his evidence before you, gives it at a farthing per 1,000 gallons lifted 100 feet, which is equivalent to 20*s.* 10*d.* per 1,000,000 gallons raised 100 feet. Mr. West and Mr. Hocking, Cornish engineers, gave all the particulars of their estimate two or three years ago before the Select Committee on sewage, Lord Robert Montagu's committee, and they give it exactly as Mr. Hawksley gives it, 20*s.* 10*d.* per 1,000,000 gallons. In Liverpool where coals are very much cheaper than they are in London, and where Mr. Duncan is certainly as economical as anybody I know, the best engine, which is the Green Lane pumping engine, does the same amount of work at 19*s.* 11*d.*; the Windsor engine, raising a large quantity of water at 24*s.* 1*d.*, and the Audley Street engine at 23*s.* 5*d.* I could give many other cases, but I think those are enough to show that in taking 21*s.*, which I did, as the cost of raising 1,000,000 gallons 100 feet, I was taking rather a low sum upon the best engines in the country, and I cannot help thinking that there must be some mistake, either wages have been omitted or there must be some other mistake in Mr. Quick's statement of 13*s.* 10*d.*, as in the Grand Junction it does cost, according to the returns made by the company, 22*s.* 6*d.*

6657. (*Chairman.*) Will you now proceed with the next branch of the evidence you wish to lay before the Commission?—With regard to insufficiency of rain, which was one of the objections to my system, I think I must have established that there is plenty of rain, and sufficient storage in the Welsh district. Then the question comes as to coloured matter. I think I have referred before to the fact that with regard to Loch Katrine, which receives the water of the hills above where the entire drainage is a peat-covered district, that all the water which falls into the loch is the colour of dark coffee when seen in bulk, and yet the effect of the oxidation and bleaching which takes place in the loch itself is such that the water, although not absolutely colourless at certain seasons of the year, yet for a large portion of the year is absolutely colourless, and in autumn and the late summer months, when heavy floods after bad weather take place, it is almost colourless, and that it is so entirely from the effect of exposure in the basin of the loch itself. The length of Loch Katrine is about seven or eight miles, the water is taken at about one-third the distance down, at about 2½ miles from the head where the river Gyle runs into it as brown as coffee, and not a mile above Strowan burn, which is a browner stream even than the Gyle, and every other little stream running into it being at certain seasons of the year charged with colouring matter. There, certainly, the effect of deprivation of colour is almost complete, and for a large portion of the year the water is absolutely as pure and as colourless as a water can be. The effect in the Welsh reservoirs must certainly be the same, especially when I point this out to you. First of all, the drainage ground of the country above those reservoirs is not covered by heather and peat by any means to the same extent to which the Loch Katrine district is. The Llanwddyn reservoir which is the one on the north, is, I think, about six miles long. The water will be drawn from the lower end, the principal feeder coming from a considerable distance above there, and therefore the water will be drawn at a distance very much greater from the point at which the turbid water comes in than it is at Loch Katrine. The large reservoirs in the lower part of the same district are also of very considerable length. The Trefeglwys reservoir, which is a large reservoir on the southern portion of the drainage, is about four miles long, and more than two miles from any place where the water would be received from the natural feeders of that lake, and more than a mile below the point at which it is proposed to divert the river Carno into it. Bala Lake is about four miles long, and it is a great deal shorter than the Llanwddyn reservoir; it is not equal in length to those reservoirs, and it is not more than three-quarters the length of the Trefeglwys reservoir, and yet Bala Lake, which receives exactly the same character of water, is also almost absolutely colourless. The Manchester water is by subsidence in reservoirs also bleached to a considerable extent, and although a system of separation is carried out there which enables them to carry the water in a pure condition only, yet there also very considerable decoloration takes place in

J. F. Bateman, Esq.

11 March 1868.

the reservoir. I mean that the red colour is taken out of the water very much indeed by exposure. But I might refer you to the evidence which was given before you in which the river Don below Sheffield, and the river Irwell between Manchester and Warrington, were adduced as instances to show how much running water was deprived of colour, but there was one special instance, namely the river at Loughborough, below Leicester. Loughborough is about eight or nine miles below Leicester. At Leicester the water was described as being as black as ink, that nothing could live in it, that the smell was objectionable, and that in every respect it was as bad as could be, but by the time it got to Loughborough, eight or nine miles lower down, it was entirely restored to its pristine condition, fish were swimming in it, and you could see every pebble at the bottom. The time occupied in flowing from one place to another, at the rate of about a mile and a quarter, which is the usual speed of those rivers, would be only six or seven hours, and yet water as black as ink at Leicester was at Loughborough restored by mere exposure to the air, and by running in the river, to its pristine condition. The water from Wales would not only be exposed for a longer period than that, and would travel a greater distance in reservoirs or lakes, where it would be allowed to subside and be exposed for a long time to the action of the atmosphere, to the sun and the air, but it would have to run about 173 miles, in an open channel for a large portion of the distance, before it reached the reservoirs near Stanmore, and it would occupy something like 140 or 150 hours in doing that instead of six or seven hours, which is all that is required in order to convert a black stream into a pure one between Leicester and Loughborough. I think I hardly need pursue that subject further. The water will be as pure water, if not purer in point of colour than that which is delivered at Glasgow, and there is no Glasgow man who does not speak in the greatest possible praise of Loch Katrine water. And it would not require filtration, because everything of an objectionable character would subside, and the water would be delivered, as it is in Glasgow from Loch Katrine, in a perfectly pure condition.

6658. (*Sir B. Phillips.*) Do you say that from the Welsh district to London it will take 140 hours?—It will run at the rate of a mile and a half an hour, and it is 173 miles from the reservoir to Stanmore.

6659. (*Mr. Prestwich.*) Do you know how many days in the year they have that clean-coloured water in Glasgow?—It can hardly ever be said to be discoloured; there is the palest possible straw-tint in a large quantity; in a bath, for instance, in the autumn months, but if you see it in a glass, or in a bottle upon the table, it is perfectly colourless; it is only when you see it at a depth of two or three feet that there is any colour at all in the Loch Katrine water.

6660. Still that shows that there is a small quantity, although it is but a small quantity, of peaty matter floating in the water?—I do not dispute that, but it is not to an objectionable extent. Then you must consider the circumstance that nearly the whole water which Loch Katrine receives when it flows in is coloured, and the conduit is wholly covered from Loch Katrine to Glasgow, and it is therefore never exposed to the atmosphere or to the light after it once leaves Loch Katrine, which is a very important difference.

6661. (*Sir J. Thwaites.*) The water in the loch itself is perfectly pure, is it not?—Yes. I was there in September last year after very heavy rain when the water was at its worst colour. I never saw it so bad. I laid down, when I made the entrance basin at the mouth of the tunnel from Loch Katrine, a layer of white quartz pebbles in order to show the brilliancy of the water; those which were there in about four feet depth of water and some fresh ones which I threw in were changed at that depth to the palest possible straw colour, and that was all the discoloration that took place; at a foot deep, or two feet, or even three feet deep, you would not have been able to detect any colour at all.

6662. Is there anything special in the Manchester gathering ground to add colouring matter to the water?—Yes, there is a large quantity of peat in the Manchester water which flows into the reservoirs, but all the discoloured water is stored in separate reservoirs, and the pure uncoloured water and the spring water is either taken direct to Manchester, or stored in other reservoirs; but a portion of that which is discoloured water after being stored for a time becomes so pure that it is also taken to Manchester if it is required. The Manchester water is very much in the condition of that Glasgow water; there is occasionally a slight tint in it, but it ought not to be so; it is merely mismanagement if there is any colour whatever in the water at Manchester. There was one gentleman who said that the water was so much discoloured in Manchester that they actually used coloured tumblers to disguise it. I am afraid my friend who stated that must have been himself deceived, and I can only account for such an extraordinary statement by this fact, that in the refreshment rooms of the railway stations in Manchester and one or two of the hotels they use hock bottles for drinking water. I was in a refreshment room shortly after that statement was made, and I said, "Why do "you use those dark coloured bottles? Is it because "the water is so bad a colour?" "Oh, dear no, sir," they said, "We will draw you a little." They did so, and I perceived no colour in it, and I said, "Why "do you use those bottles?" They said, "It is "because they are cheap, and if they break it does "not signify much." And, besides, dark-coloured bottles are considered to keep water cooler in summer. I do not think a coloured tumbler was ever used in Manchester—except it may be an ornamental Berlin glass one—not as a common thing; certainly it is an entire mistake.

Another point which was made a matter of objection to the Welsh scheme was that there would be mischievous effects produced from the River Severn by loss of scour. That is a point of some importance, and I have made some calculations upon what the effect of the abstraction of the water would be. We shall interfere more or less with the water flowing from about 130,000 acres, which will supply 250,000,000 gallons a day; that is exactly one-twentieth of the whole acreage of the River Severn down to Gloucester, which is 2,600,000 acres. That is all we should interfere with when we came to take that quantity of water, but allowing for the great amount of water which would fall upon the mountain district as compared with the lower district, we may assume that if we bottled the whole of the water, and kept it back, it would be probably about one-fifteenth of the whole. But then we only take 40 inches out of 61 or 62 inches, which is the average amount of rain as I showed the other day; so that we should only interfere, if we even bottled the whole of it up, with two-thirds of the water coming from 130,000 acres. That would be about one-twenty-second or one-twenty-third part of the whole, but for a long time we should not take more than half of that. I have endeavoured to ascertain what the maximum flood would be below Gloucester, or at Gloucester exclusive of the tide; I cannot get a return as to the quantity of water in a flood there, but the evidence of one or two witnesses before you is that the maximum flood in the Thames is 25,000,000,000 gallons per day, and that is equivalent to 1·73 cubic feet per minute from each acre of drainage ground. I have assumed that the Severn floods would be two cubic feet per minute from each acre because it is a more precipitous and more mountainous district in the upper parts; I had occasion in investigating the inundations in the river Shannon for the Government some years ago, to ascertain what was the maximum flood to be provided for in all the rivers in the basin of the Shannon, and from information which was received from Mr. Forsyth, the engineer of the Board of Works, who had paid

much attention to the subject, and from my own measurement of the maximum floods in several parts of the Shannon, I found that 1 foot per minute from each acre is a very considerable flood, and that there is no river falling into the Shannon even where the volume of the flood is not checked by any lakes, which very materially modifies the amount of flood—there is no river which sends down more than 1·54 cubic feet per minute from each acre of ground, so that a flood of 1·73 feet from so large an area is a very considerable flood. I could give many instances of floods being very much larger than that from small areas, but not over so large an area as this. Taking it, however, at two feet per minute from each acre, the flood at Gloucester where it enters what may be considered the tide-way added to the quantity of water which the tide itself holds up, and which runs out at every tide, would be about from $\frac{1}{40}$th to $\frac{1}{50}$th part of the whole amount of the water in the estuary above Sharpness point. I have endeavoured to ascertain the quantity of water in the estuary by taking sections and by taking the rise of the tide and the fall of the tide, and I have ascertained from information the velocity at which the water runs past Sharpness point, and I have taken the quantity of water running up and down in each tide, and that is the result. There is a very small amount of traffic upon that part of the river which lies above Sharpness point. At Sharpness point the tide rises 32 feet 6 inches. Nothing but a few barges go up from there to Tewkesbury, a few sea-going vessels of about 150 tons burthen go up as far as Newnham, and all the rest of the traffic is carried on by the Gloucester and Berkeley canal, a ship canal constructed expressly for the purpose of avoiding the difficulties of the estuary in that portion of it; and I ascertained from information upon the spot also that one of the greatest difficulties which they have to contend with is the excessive floods which occasionally come down, that a moderate flood does them good, but that an excessive flood following upon the ebb-tide disturbs the channel so much that a bad naver gation is the consequence. That is quite consistent with what one knows and observes in other parts of the country, and therefore, I cannot think that the abstraction of so small a quantity of water as we shall abstract, will produce any mischievous effects upon the upper part of the estuary of the river Severn. I give that opinion for what it is worth. I can only express it as an opinion; I cannot prove it as I have endeavoured to prove all my other statements.

6663. It was stated in evidence that the advantage of those floods was to prevent the silting up of the mouth of the river, which would be the result if you abstracted that large quantity of water?—There is no silting up now and there would probably be no silting up because the quantity of flood water would still be very considerable. The ordinary volume of the stream would be very materially increased. If I am to take the evidence which was given by Mr. Hawksley that the dry water volume at Tewkesbury or Worcester, one or the other, was about 90,000,000 gallons a day, we should add 30,000,000 gallons a day to that quantity from the reservoir by reason of the compensation that we are proposing to give, which would make it 120,000,000 gallons at that part of the river which would be constantly working upon the bed, and would produce a very considerable and useful effect. Then the effect of the interception, the capturing of floods, as it was called, by our reservoirs, would be this, that when the reservoirs were empty the floods would be captured, but when the reservoirs were full, and they would be full at certain seasons of the year because we can only take two-thirds of the water in average years, then the floods would go down just as they have gone, simply moderated to a limited extent by the area of the reservoirs producing a more regular effect upon the lower reaches of the river. Therefore you would have every year floods as big as they ever were, but you would not have so many of them.

6664. (*Mr. Harrison.*) You would quite expect, you should not, that the question of the effect upon the river would be the great battle-field before any Committee of Parliament?—I believe it would be the only battle-field upon which they could hold their ground; I think it is very likely it might be so.

6665. In the case of the Glasgow Waterworks Bill, did not the officers of the Admiralty report that your abstraction of water from Loch Katrine would affect the navigation of the Firth of Forth?—They reported one year, that the anchorage of St. Margaret's Hope which is 60 feet deep would be destroyed, and they reported nothing against us the second year.

6666. (*Sir J. Thwaites.*) What has been the result upon that anchorage?—Nothing that I am aware of; it is not destroyed certainly, and there has been no injurious effect whatever produced.

6667. (*Chairman.*) What observation have you to make with reference to the danger of large reservoirs, which has been urged as an objection to your scheme?—If the Commission think it is necessary that I should go into that, I should be very glad to do so, but I think you have sufficient evidence upon that point.

6668. (*Sir J. Thwaites.*) I presume with reference to that question, that there is no difficulty with ordinary care in making a dam sufficiently strong to resist the pressure of water of ordinary height?—No, not if the ground is properly selected. Of course there is ground in which it would be almost impossible to make reservoirs, but in the cases of my proposed reservoirs, the sites of some of them are almost absolutely impervious, being unfissured silurian rocks, which are excessively dense, and there is no difficulty whatever in getting perfectly watertight foundations; in other cases, take the Trefeglwys reservoir for instance, the bed of the valley there is all very hard clay, and shale beneath the clay, and shale is always a material that we desire for the foundation of reservoir embankments. The highest embankment is only 80 feet, they vary from 70 to 80 feet, and there are many embankments in this country very much higher than that, and in much more difficult and dangerous positions. In fact one or two embankments which have burst, bear testimony to the safety with which embankments may with ordinary care be constructed. The Bilberry reservoir which burst in 1852 was so badly constructed that the water leaked through the bottom as rapidly as it entered, it never went over the waste weir, and the only occasion, on which it ever rose to the top was the occasion on which it was cut down, and yet it stood in that insecure condition, neglected by the people who ought to have attended to it for a great number of years, after its construction.

6669. (*Chairman.*) The next point of objection to your scheme is the danger of freezing in the aqueduct, what remark have you to make upon that?—I cannot myself apprehend any difficulty about freezing, you have had some evidence given before you with reference to the danger of freezing. It has been stated that the water in this canal would become jelly ice, and that if it travelled at all, it would go glacier fashion, and that it would become glue and would not move, I think all those are rather figures of speech than anything else, and that there is really no serious objection which can be urged against the scheme on that score, The Commission have had some evidence as to the effect of frost upon the New River in 1813–14 and that is the only instance which has been adduced by anybody. In that one year certainly, when a fair was held upon the river Thames, there was an interruption to the flow of water. The quantity of water which would then be taken by the New River Company I have not been able to ascertain, but it would be very much smaller than it is now, it is only a shallow narrow stream, and it would be much more liable to freeze than such a conduit as I propose, which would be 10 feet deep in water, and about from 26 to 30 feet wide. It would be deeper than the river Thames at Kingston, and in its ordinary state the river Thames never becomes jelly ice, it never becomes a glacier in modern times, and it never becomes glue, it has always proceeded to the sea without inundating the

J. F. Bateman, Esq.

11 March 1868.

adjacent country, though its surface has on one or two occasions been covered with ice above old London Bridge. Since old London Bridge has been removed, that does not occur, and no fairs have been held upon the ice since. Then in the case of the Manchester Waterworks which have a great number of open aqueducts, not more than three or four feet deep, and some of them not so deep as that, at elevations of 700 to 1,000 feet above the level of the sea, in a cold exposed country, they never freeze. There is a little interruption now and then by a little floating ice upon the surface which is easily removed. But that amounts to a very small objection indeed, and the only evidence which you have had really before you, with the exception of the instance of 1813-14, is that of the engineer of the New River Company, who states that they have in severe winters a little trouble, and that the cost of breaking the ice is from 500*l.* to 700*l.* in a severe winter. That of course is not every winter, it is merely in a severe winter, and just as much as rivers now flow (for this would be a river of very considerable size) without doing any injury to the adjacent country by refusing to go on, so this river would flow; I cannot conceive the possibility of its being any otherwise.

6670. (*Sir J. Thwaites.*) It might lessen the capacity of discharge, might it not?—The moment it freezes over then, of course, it is a covered conduit, and the friction then is somewhat increased, but the result of that would simply be to raise the surface of the ice until it got a little extra depth, or until the extra sectional area with the reduced velocity balanced the account. When covered by ice it would be exactly like a covered conduit, and there would then be no farther difficulty until the ice broke up. It might require some cost and some labour and some attention to get quit of it then, but that is the only thing. It is very different to a canal inasmuch as a canal is in stagnant pools, but this would be a river constantly flowing, with a speed of a mile and a quarter or a mile and a half an hour.

6671. Have you observed, in long tunnels, what length is necessary to raise the temperature of the water?—I cannot tell you that, but I know this, that in the winter of 1860-61, which was the severest winter that we have any record of—a much severer winter, as far as the record goes, than the winter of 1813-14—the temperature fell in that winter to 12 and 14 degrees below zero—about 44 or 45 degrees of frost,—and we have no record in this country of anything equal to that previously; that was the year after the Loch Katrine waterworks were completed. The works were only completed so as to take the water to Glasgow entirely, early in 1860. I was very anxious about my green masonry, but Loch Katrine never froze: the water was never lower than 39 degrees of temperature, that is to say, 7 degrees above freezing point. There was not a particle of ice upon the whole of the surface of the loch, and in the 26 miles which the water had to travel between Loch Katrine and the Mugdock reservoir, near Glasgow, it gained two degrees of temperature, and it emerged at 41 degrees.

6672. (*Chairman.*) When you speak of the temperature in that year being 45 degrees of frost, of what place are you speaking?—That was in Scotland, and in many parts of England it was the same also.

6673. Was it not colder in England at that particular time than it was in Scotland?—It was generally, but it was not in the neighbourhood of Loch Katrine; in the neighbourhood of Loch Katrine it was 12 degrees below zero. Every part of Scotland being so near the sea the temperature is generally higher than in the interior of England, but in the neighbourhood of Loch Katrine it was 12 degrees below zero.

6674. (*Col. Harness.*) Was 39 degrees the temperature of the bottom of Loch Katrine?—No, that was the surface temperature; we could not tell the temperature of the bottom; it is 800 feet deep.

6675. (*Sir J. Thwaites.*) You do not apprehend any danger, do you, from the mixing of snow with your water in the aqueduct?—Not the slightest; a little trouble and expense occasionally, but danger and difficulty none.

6676. (*Chairman.*) Speaking from your own experience, you have not found any inconvenience in the system that you have now in operation?—That is so. I have never experienced any serious inconvenience. There has been a little trouble in severe winters, but nothing like a serious inconvenience—nothing which could be urged as an objection to my proposed scheme.

6677. (*Sir J. Thwaites.*) The Glasgow aqueduct is under cover all the way, is it not?—Yes, the Glasgow aqueduct is under cover all the way, but in Manchester we have many miles of open watercourse, much smaller, and of course a frost would have more effect upon a small one than upon a large one.

6678. (*Mr. Prestwich.*) Are not the reservoirs at Manchester subject to freezing?—Very little; scarcely ever. I do not think that any of the larger reservoirs in the Manchester waterworks have ever been frozen so as to bear.

6679. The great depth of Loch Katrine has no doubt very materially to do with its freedom from freezing?—Yes, I am speaking of the large reservoirs which vary perhaps 60 to 70 or 80 feet of water, and I do not think they ever freeze sufficiently to bear. I never remember it. Of course the water is kept warm by the great depth, and in the very large bodies of water which I propose the same effect would be produced.

6680. (*Chairman.*) The hardness of the present water is considered by some persons to be unobjectionable, and some persons are of opinion that the present water would be preferable to soft water. Have you any remarks to make upon that point?—You have had before you nearly 50 witnesses, of those 16 had not any occasion to express an opinion upon the quality of the water, and they did not express an opinion, it did not fall within the scope of their evidence. You have had 27 who have all expressed an opinion in favour of soft water, some of them very strongly in favour indeed. You have one single gentleman who has expressed a decided opinion in favour of hard water, and you have had one gentleman who has expressed a qualified opinion in favour of hard water. Amongst those who have expressed a very strong opinion in favour of soft water are Mr. Rawlinson, professor Way, professor Ramsay, Mr. Duncan, Dr. Lyon Playfair,—to whose evidence I must especially draw your attention,—Mr. Simon, Dr. Farr, who also very specially referred to it, Dr. Parkes, and Dr. Frankland, and with him Dr. Odling. I would refer upon that point to the evidence which I gave on the first occasion, on the second day on which I had the honour of being examined before you. I read that evidence over this morning, and I do not think I can add much to the facts which I then stated, nor put them in a better form. I mentioned that in my own house I saved half the quantity of soap which I formerly used, by the introduction of soft water at my house in the country, and that I saved from 4*s.* to 5*s.* a head in a year. I find that the soap which I buy for my household in large quantities cost me, before the introduction of soft water, between 10*l.* and 11*l.* for about 15 months' consumption, that since the introduction of soft water, which I introduced in the autumn of 1864, the soap which I previously used in 15 months now lasts me more than two years, my household consisting almost exactly as nearly as a household can do of the same number of inhabitants, and under the same conditions, in fact if anything there is a larger consumption of soap now going on, or rather, the operations which require soap are now of a more extended character than they were previously to the introduction of soft water. I save 5*l.* a year, and if I measure that by my population by from 20 to 25, I save from 4*s.* 6*d.* to 5*s.* per head per annum in the use of household soap alone. This does not include the soap

which is used in the family bed rooms, not toilet soap, but merely the household soap and the soap used by the servants. I simply add that to the evidence which I have already given.

6681. (*Mr. Prestwich.*) What was the hardness of the water which you previously used?—I have not had it analysed, but it certainly was harder than the London water. I should suppose it would probably be from 20 to 25 degrees of hardness.

6682. Was it water out of beds of gravel, or what?—It was a water out of the lower greensand from a bed of limestone which is just on the level of the river. The Alton branch of the river Wey runs through my property. I get hard water exactly on the level of the river, about 21 feet below the level of the house, and it is, I presume, the lime or chalk in the water of the river which gives the hardness to the water. The soft water is about six-tenths of a degree of hardness. I bring it about a mile; it comes from the lower greensand also, but some distance, 20 or 30 feet above the level of the river.

6683. The water of that district generally is very soft water, is it not?—Generally very soft water. I may observe that if the saving were only 2*s.* a head a year upon the population of 3,000,000 in London, that would be 300,000*l.* a year, the saving of soap alone, to say nothing of the wear and tear of clothes and all other things which might enter into the consideration; and the saving in soap alone would pay the interest of the whole outlay which is supposed to be necessary.

6684. Could you ascertain the hardness of the water which you were using before, and put it in?—I will endeavour to do so. The spring itself, which I now bring to the house, Dr. Frankland is analysing for the purpose of giving some information with respect to it before this Commission, I believe.

6685. (*Chairman.*) The next point is the danger of interference with the conduit, and the interruption of the supply in troublous times, have you anything further to say upon that?—I think I have already gone into that. I may merely observe that I do not see very well how anything could be easily done to intercept the supply to London.

6686. Some doubts have been expressed as to the possibility of bringing water so great a distance as 180 miles from Wales to London; what is your view upon that subject?—It seems to me quite as easy to bring it 180 miles as 18 miles if you have the proper appliances, nor do I now quite understand where the difficulty is supposed to exist. It may be more liable in proportion to its length to be interfered with, but there is hardly anything which can be easily interfered with. Much of it would be in tunnel, and it would be nearly the whole in the solid, because in constructing works of this kind I avoid embankments as far as possible. I put nothing of this kind upon embankment as a matter of practice, and only here and there over a gorge would the aqueduct be susceptible of being injured. Stop-gates and other appliances would be introduced for shutting off the water here and there for the purpose of examination, or for repairs, and there is no repair that I can conceive of which would take more than eight or ten days to execute, and you have service reservoirs holding three or four weeks' supply, and during the time of the repairs the water would be drawn from them exclusively. I cannot myself see any difficulty whatever.

6687. Do you draw any comparison between the mortality of those towns which have a supply of hard water, and those towns which have a supply of soft water?—With your Grace's permission I should like to make a few observations upon the tables put in by Dr. Letheby upon that point. Dr. Letheby gives a number of towns, distinguishing those having water of more than 10 degrees of hardness as hard water supplies, and under 10 degrees of hardness, as soft water supplies. Ten degrees of hardness is a perfectly fanciful distinction, the proper distinction between hard water and soft water is just as clear as the distinction between day and night. The terms "hardness" and "softness" were first reduced to anything like scale by Dr. Clark who introduced the soap test. All water that does not curdle soap is soft water, and all that does curdle soap is hard water. All water containing less than four or five grains of lime or other soap-destroying ingredient will not curdle soap, and therefore that is soft water; all water containing more than five grains will curdle soap, and there begins hard water. Anything above that is purely an arbitrary and fanciful distinction which anybody might put at anything he chose, and therefore that table which Dr. Letheby gives is not a table correctly describing towns with hard water or with soft water at all. Again, many of the places which he adduces are small places in notoriously healthy countries with hardly what you may consider an urban population, almost a rural population, and they are not at all to be compared with a dense population in a city like London.

6688. (*Sir J. Thwaites.*) With regard to the point at which water ought to be declared hard or soft, is it five degrees or what is the point?—About four or five degrees. Just as day fades into night and night fades into morning, so softness and hardness die away, the one into the other. About four or five grains of lime, or other soap destroying ingredient, is just the turning point. You can hardly tell to a degree. We may put it in this way, all under four degrees is certainly soft water, and all above five is certainly hard water, of course varying in hardness as the night varies in darkness. In order to show how utterly impossible it is to draw any conclusion from the mere fact of mortality, I will refer to the cases of Manchester, Salford, and Chorlton, they are all supplied with the self-same water from the same district, and two of them are, perhaps, of precisely the same character. The mortality of the three places combined reckoning upon the standard mortality of the country is from 29 as nearly as possible to 30 per 1,000, reckoning upon the actual population it is 28 per 1,000, and the total population there is 479,000 persons. The city of Manchester only contains 236,000 persons, the mortality upon the standard population of the country is $33\frac{1}{2}$ and upon its own population it is $31\frac{1}{2}$ per 1,000. Chorlton, which is a part of Manchester, and contains 147,000 inhabitants has no greater mortality than $25\frac{2}{3}$rds per 1,000 upon the standard mortality of the whole country, and as nearly as possible 24 upon its own population. So that in the same town you have a variation from 32 to 24, the same water being delivered to both parts of the town, showing that the mortality really gives you no indication of the effects of hard or soft water.

6689. (*Sir B. Phillips.*) Are they all supplied from the same source?—Exactly the same, and yet you have a mortality in one part of the town of 32 per 1,000, and in another part of the same city you have a mortality of 24 per 1,000, the smaller population being that of Chorlton—146,000 persons.

6690. Is not Chorlton less closely populated?—Yes, there is a difference in that respect; there are other causes than the water. No doubt it is attributable to the fact of the population being less dense, as well as to other causes. I will not go further into that, because what I have just mentioned shows that that is not a test to apply as to the effect of hard or soft water upon the health of the population. I should like to add, upon that point, a letter which I had intended to put in before with reference to the water of Dublin, which has recently been introduced into a portion of the city from the new works upon the river Vartry. It is a letter from the principal of the St. Mary's Industrial School, in Stanhope Street, Dublin, and was sent to me by Sir John Grey, M.P. It is in these terms:—"It is with much pleasure "I intrude upon you these few lines, to say what "great satisfaction and comfort we have since the "new supply of water has come into operation. "We consider it a great saving of expense to a "large institution like this, where there is an ex-"tensive laundry. The softness of the water in the

J. Bateman, Esq.

11 March 1868.

"present supply has enabled us to give up the use of "soda, which is necessary in other cases to make the "soap act on the linen. It is not at all required with "the Vartry water, which in its own nature is soft "and mellow. We find a saving of at least a third "of the quantity of soap before used by us for laundry "purposes. We consider the water a great blessing, "and with the city and public at large must feel "grateful to those who have exerted themselves to "procure for us such a boon." It is merely an independent confirmation of my statement that from one-third to one-half the soap, from whatever part of the country the information comes, is the actual saving by the introduction of soft water. The Vartry water is equal pretty much to the Manchester water. It is not perhaps quite as soft as the Loch Katrine, but not far off; and the water for which it has been substituted is the water of the Grand Canal and the Royal Canal, which are about from 18 to 21 degrees of hardness, or rather harder than the London water.

6691. (*Chairman.*) Is that saving in soap from the use of soft water as compared with hard water produced when the water is cold, or after boiling?—There evidently it is after boiling, because it is as to the laundry principally that they speak of it.

6692. We have had it stated in evidence that, given a hard water and a soft water, if you boil both, there is very little difference in the hardness or the softness of the two waters after that process; do you agree with that?—Yes, if you boil the water long enough: but water seldom is boiled long enough. Dr. Frankland, in the evidence which he has given you, shows that ordinary boiling scarcely reduces the hardness; he takes the water in his own house and in the Athenæum Club, and he says that the water which he draws the first thing in the morning, having been under heat all night, is many degrees softer than the cold water, but that after that water has been drawn off during the remainder of the day, there is very little difference between cold water and the hot water.

6693. (*Mr. Prestwich.*) Reverting to the more important consideration of the effect of water upon health, which you have just touched upon, what you have observed with regard to different portions of Manchester would be applicable to all large towns; that is to say, Liverpool, or Sheffield, or any other large town would show the same differences of effect taking different portions of the town, but taking it in the aggregate, can you show any different result arising from the use of soft water as compared with hard water in any towns which have been supplied with soft water?—It is very difficult to do that. My own firm conviction is that soft water is very much more wholesome than hard water, but I do not think that the use of hard water leads to fatal diseases, and on that account probably the effects of water have not been observed by medical practitioners. But I am quite sure that anybody who is affected with particular disease, calculus, for instance, will speak as to the beneficial effect of soft water as compared with hard water; otherwise I do not know that there is much to prove it, but certainly soft water is wholesome.

6694. Have you any returns from any towns in which soft water has been introduced to show the difference in the health of the population?—In Whitehaven, which was supplied with hard water and very badly supplied, a fresh supply was introduced some 20 years ago. The mortality at Whitehaven, on the average of the four years previously to the introduction of the Ennerdale Lake water, which is a very soft water, was about 35 or 36 per 1,000. In the four years succeeding the introduction of that water it fell to an average of 23 or 24 per 1,000, and the fourth year it was only 19 per 1,000.

6695. Has there not been a further alteration in the mortality since that period?—I have been told that the mortality has increased in Whitehaven since then, but for four years previously to the introduction of soft water, and for four years subsequently, that was the state of things. I had occasion to investigate it at that time because we were then fighting the question of soft water for Glasgow, but what the mortality is now I do not know. In that particular case the introduction of water of any kind might possibly have produced the same effect, but it was soft water, and the mortality was reduced; there was no other cause apparently to account for the difference, and upon the introduction of soft water this remarkable fall in the mortality occurred.

6696. Was the supply in any way defective in quantity before that?—Yes, it was, certainly.

6697. (*Sir J. Thwaites.*) Is it not difficult to determine the question as to the effect of hard and soft water upon the health, so many other causes being in operation; for example, in the case of the small town to which you have referred there might have been many deleterious substances in the water which might have affected the health of the inhabitants apart from the hardness of the water?—No doubt.

6698. Then there are sanitary arrangements frequently accompanying a fresh supply of water which would have a tendency to improve the public health?—Yes, no doubt. In the city of Manchester, a good while ago Dr. Percival resided who was a very eminent physician in his day, and he wrote upon the Manchester water which was then obtained from the new red sandstone and contained several earthy salts, and he especially attributed many of the complaints to the water which was then used, and he mentions what they were. Now those complaints to a great extent have ceased, they are not now common complaints in the city as they were in his time, and the same negative evidence if it can be considered negative evidence, occurs at Paisley where hard water previously existed and soft water was afterwards introduced, and where from the evidence of those who know the circumstances complaints of stone in the bladder which were common before ceased.

6699. (*Mr. Prestwich.*) I presume the water from the new red sandstone contained sulphate of lime?—Yes, what he calls selenite. I do not know what he means by selenite, but he said it contained selenite to a great extent. One argument which I have heard very stubbornly used in favour of hard water is that it is absolutely essential to the formation of bone, but the finest and most muscular men, and men of the most bony development that we have are men who live in soft water districts, and cannot get hard water, and those who live in districts where they get nothing but hard water are certainly the smallest men, and of the smallest physical development that we have in Great Britain.

6700. The oatmeal they use in the north contains sufficient carbonate of lime to render them independent of it in the water?—I suppose they have other things to live upon; but what I mean is, that they do not depend for their bones upon the water they drink.

6701. (*Chairman.*) With regard to the area from which water could be obtained, are we to understand that you think that the area could be increased if it was found necessary?—Yes. I gave some evidence upon this point before. It was alleged that it was impossible to get an additional area; but I have upon the map which is before the Commission shown the additional area which may be obtained. It is approximately correct; it shows the area which may be added to the area which I have already included. First of all there is the piece which is striped with green, which is the River Severn proper. That is a district which I omitted in the first instance; because at the time the investigation was first made, there were certain lead-workings upon it which I was anxious to avoid; but when Mr. Pole was over the ground he found that those lead-workings had ceased, and that that water was as good and as fine and pure as any other water in that district. That area contains 12,301 acres, and that would give 2,225,000 gallons per 1,000 acres; that, therefore, would give 18,000,000 or 20,000,000 gallons a day more for the supply of London, after giving compensation. Then there is

that part to the north of the pink which is coloured yellow; all that is a district which may be brought into the supply; and the part which is coloured yellow to the east of the Trefeglwys reservoir; both those districts being in the Severn Valley may also be added to the drainage ground; and those parts which are coloured dark orange, lying to the south of the green part, are in the valley of the River Wye, and they may all be brought into the Trefeglwys reservoir, or to other suitable situations, for conveyance to London. Altogether those additional pieces contain 117,399 acres, and they would supply to London, if the water were stored, upwards of 200,000,000 gallons a day, after compensation was given. The following table will give the additional acreage which may be obtained:—

Welsh Scheme.

Memorandum of Area of additional Drainage Ground, contiguous to the proposed Scheme, which would be available at a future time for extending the supply.

	Area in acres.
Main branch of the river Severn, omitted from present scheme on account of lead mines, which were understood at the time the scheme was laid out, to pollute the stream. Mr. Polé finds that the mines are insignificant, and that the stream is consequently available for purposes of supply - - - - - - -	12,381
Afon Marteg Valley, to the south of the Dulas and Twlch streams. In this valley a reservoir has been surveyed of a capacity more than sufficient to utilize the water of the district -	4,450
The river Wye, above Llangurig and the stream flowing from the hills to the south of that place, 27,270 + 5,679 acres - - - - -	33,949
The hills and streams lying to the west of the Dulas and Twlch valleys, and to the south of the Llanidloes - - - - - -	16,665
The district to the north-east of the river Vyrnwy, 41,113 + 8,841 - - - - -	49,954
	117,399

All this additional drainage ground lies on the east of the mountain ranges of Plynlimmon and Aran Mowddy. Considerable drainage ground could also be obtained on the west side of the hills, taking the upper portions of the Dyfi and other streams now flowing into Cardigan Bay.

6702. (*Sir J. Thwaites.*) That gathering ground which you have now referred to, colored orange, is not so good as the upper part, that is to say, it is not so free from agricultural operations?—The upper portion of it, on the flanks of Plinlimmon, is quite as free. There is no doubt a little difference, but the Severn goes quite up to the slopes of Plinlimmon, and this brown part on the map goes up to the very summit, and all that district is quite free as from objection as any other part (*describing the same*). Some of the parts are certainly more or less cultivated, That is altogether exclusive of anything which may be obtained from the western slopes of those ridges if it should be considered desirable to go further, but you have in that district upon those coloured patches, 500,000,000 gallons a day for London and the district, and I should think that is sufficient to contemplate for a long time to come.

6703. (*Chairman.*) Have you any further remarks to make upon Messrs. Hemans and Hassard's scheme?—I beg leave to hand in an estimate of the cost of obtaining water from Cumberland on the same scale of prices, and for the same class of works as my own estimate is based upon, because it is impossible to compare the cost of two different works, except the works are laid out in the same manner, and the same prices are applied to them. I have not a word to say against the Cumberland district as being a proper district for supplying water; the water is abundant and good, the drainage ground is good, and I have no objection whatever to make to it, but it lies at too great a distance from London to be available to London as compared with districts which are nearer. I know the lake district well. I have lived in it, and made reservoirs and waterworks in it, and I know all the circumstances, and there is nothing about the scheme which I have any occasion to complain of, but the cost of collecting water and storing it is quite as great as the cost of the collecting and storing water in the Welsh district, although they have the advantage of starting with natural lakes and in Wales we have to make them artificially. My estimate of the cost of constructing the reservoirs which I have laid out and collecting all the water, upon very carefully considered plans, is 1,060,000*l.* That includes all the flood-water courses and the reservoirs and all means of collecting and storing. The cost of storing and collecting water in the Ulleswater scheme of Messrs. Hemans and Hassard according to their own estimate is 1,013,000*l.*, being only 46,000*l.* less than my estimate for the Welsh district. I adopt their estimate, I will not find any fault with it, but I may observe that my own estimate for the works which are required in that district would have come to more than that, it would have been some 200,000*l.* more than the cost of collecting in the Welsh district. Therefore although they start with natural lakes, yet the other disadvantages of making very large flood-water courses and tunnels for the purpose of conducting water from one valley to another, and the cost of making embankments at Haweswater, Thirlmere, and other places balances any other advantage, and it makes the cost as great in treating their district as the cost would be in treating the Welsh district. But then comes the very important difference of distance. From my reservoirs in Wales to the service reservoirs near Stanmore it is only 171 miles in the one case and 173½ miles in the other. Messrs. Hemans and Hassard have fixed upon the same place for their service reservoirs as I have myself with a difference with respect to level for their service reservoirs, but the distance which they have to bring the water is 270 miles. They have further than that the disadvantage of having only about the same amount of elevation to start with which I start with. I think they start, if I remember rightly, at something like 465 feet. I start at 450 feet, but they have a greater distance to perform their journey in, so that I am enabled to give to my covered aqueducts 14 inches fall in a mile, while they can only give 6 inches. I give 6 inches of fall a mile to my open aqueduct, while they can only give 4 inches, and I give 5 feet fall in a mile for the syphon pipes, while they only allow 20 inches. The consequence of that is that their works must necessarily be on a larger scale to convey the same quantity of water. To get over the difficulty of fall they have proposed to make wrought-iron tubes of 8 feet in diameter for crossing those parts of the country in which they require to use pipes. They cannot make an open or covered aqueduct of the ordinary construction, and by the adoption of that system they not only do with a fall of 20 inches, as compared with 5 feet in a mile, but they save about three millions of money, as compared with the cost of introducing cast-iron pipes. Then comes the question of whether wrought-iron pipes or tubes are suitable for the conveyance of water. Wrought iron oxidises very rapidly in soft water. You cannot protect wrought iron as you can cast iron in the way I showed you with a pipe the other day. I have tried it over and over again, but the hard epidermis of wrought-iron which is all rolled, is such that you cannot burn the asphalte coating into it as you can into cast iron, which is to a certain extent porous and would absorb a certain portion of the asphalte at the proper temperature when it is immersed in it. I have tried it over and over again, because I have been very often anxious to use wrought-iron, but the consequence is that everything of that kind which you put upon wrought iron scales off. In order to obviate the difficulty of corrosion, Mr. Hemans and Mr. Hassard proposed to line the pipe throughout with a certain thickness—about half an inch in thickness. I think—of Portland cement, but that will scale off, I have not a doubt, in

J. F. Bateman, Esq.

1 March 1868.

the same way as any other coating will scale off, because the scaling takes place in consequence of the rust which occurs upon the surface of the iron, and in coating cast-iron pipes, if we allow rust at all to exist before the pipes are coated the coating all comes off; the rust goes on beneath the coating and throws it off, You cannot put on a Portland cement lining without wetting it, and at the same time you wet the iron, and corrosion will take place. You cannot make a coating simply of half an inch of Portland cement so water tight that under no pressure shall it be impervious to water, and under 200 or 300 feet of pressure, which it would be liable to, the water would penetrate down to the iron and corrosion would take place, and upon the corrosion taking place the Portland cement lining would fall off and would expose the iron to the active corroding operation of the soft water. However, giving them the advantage of the wrought-iron tubes, but putting everything else upon the same scale of prices, taking the same class of work and the same scale of prices as those which I have adopted in the estimate for my own scheme, the difference is this. From Wales, for 230,000,000 gallons a day, my total estimated cost is 10,317,205*l.*, being at the rate of 44,823*l.* per 1,000,000 gallons. Messrs. Hemans and Hassard's own estimate for 250,000,000 gallons is 11,679,260*l.*, being at the rate of 46,717*l.* per 1,000,000 gallons; that is their own estimate upon such a class of work as they have adopted. If it is estimated according to the class of work which I have adopted and the scale of prices which I have allowed, but adopting their 8 feet tubes, the estimate for their works comes to 18,929,914*l.* for 250,000,000 gallons, being at the rate of 75,720*l.* per 1,000,000 gallons; and if cast-iron pipes were to be used instead of wrought-iron tubes, the estimate of the Cumberland scheme would be, 21,988,664*l.*, or, per 1,000,000 gallons, 87,954*l.* I will not say another word upon their scheme in any way. There are difficulties with reference to getting over some parts of the country which are very great indeed. I will not refer to them, but, simply putting both estimates upon the same footing, their estimate must of course be more, in consequence of the greater distance and the larger scale of work which they must adopt. I will here beg leave to hand in the following table:—

TABLE showing comparative Cost of obtaining a daily Supply of 230,000,000 Gallons from North Wales, and 250,000,000 Gallons from the Cumberland Lakes.

——	Gallons daily.	Total estimated Cost.	Cost per Million Gallons.	Distance to Stanmore.	Fall per Mile.		
					Covered Aqueduct.	Open Aqueduct.	Syphons.
		£	£	Miles.	Inches.	Inches.	Ft. ins.
From Wales - - - -	230,000,000	10,317,205	44,823	171 or 173½	14	6	5 0
From the Cumberland Lakes according to Messrs. Heman's and Hassard's estimates - -	250,000,000	11,679,260	46,717	270	6	4	1 8
From the Cumberland Lakes according to class of work and scale of prices adopted by Mr. Bateman—if wrought-iron tubes, 8 feet diameter, be adopted - -	250,000,000	18,929,914	75,720	270	6	4	1 8
From the Cumberland Lakes according to Mr. Bateman's estimate,—if 4 feet cast-iron pipes be used instead of 8 feet wrought-iron tubes, as proposed - -	250,000,000	21,988,664	87,954	270	6	4	1 8

6704. (*Sir B. Phillips.*) You say that to bring 250,000,000 gallons of water from Cumberland according to their prices will cost 11,679,000*l.*?—Yes.

6705. If the works are carried out in the same way that you propose to carry out yours, they will cost 19,000,000*l.*?—Yes, that is so.

6706. Wherein lies the difference in the construction of the works?—In the greater distance, they have one hundred miles greater distance to bring the water.

6707. But their estimate with which you do not agree, is 11,679,000*l.*, that is to say, supposing they carry out the works as they propose to do?—That is their estimate. If the estimate is made exactly upon the same scale, and upon the same prices, and the same class of works that my estimate is based upon, which is the only way in which you can compare the two, then it would cost about 19,000,000*l.*

6708. (*Sir J. Thwaites.*) You do not differ do you as to the sustaining power of the culvert?—They have to increase the dimensions of their culvert in order to compensate for the greater fall.

6709. But you do not differ from them in calculating the capacity of the tunnel at the given fall which is 6 inches per mile?—I do not find any fault with that. There is one great work which they have at the commencement; they have to pass under Kirkstone Pass, which is one of the highest passes in England, some 1,200 or 1,300 feet below the level of the summit, and there is a mile and three-quarters which they propose to tunnel without shafts, adopting the system of working which has been adopted in the Mont Cénis tunnel. I do not of course mean to say that that could not be adopted.

6710. They have taken all that I presume into consideration in their calculation. It appears such a monstrous difference between the two estimates that they should estimate their work at 11,679,000*l.*, and that your estimate for the same work over the same ground is 19,000,000*l.*?—It is not the same work.

6711. (*Mr. Harrison.*) You have got a given fall per mile which is greater than theirs, therefore your general works are less in extent than theirs?—Yes, I require a conduit of smaller dimensions.

6712. On the other hand they have taken a very much less fall per mile, and they require a much larger section; but they say that in consequence of the diminished velocity they are able to make it with a less amount of protection in masonry work; assuming that to be so, does not it amount to this, that supposing it were put into the hands of either yourself or Mr. Hemans to do, and supposing it were desirable to apply their section and their description of works to yours, it would be quite applicable?—Yes, just the same.

6713. Whereas in the case of the Cumberland scheme they could not apply your sections and your mode of doing the work to theirs?—They could not. And if my fall were considered to be too much, which it certainly is not, I could reduce the fall by stop-gates here and there, and so make the fall exactly the same as theirs. But their works also are of a very much heavier description, and they have in addition to a much greater length a very much greater proportionate length of syphon work, which is a very expensive portion of the work, than I have. And there is one point which I must also mention, in contrasting one scheme with the other. Here is every detail of the cost of their work upon my own scale of prices exactly; I have worked them out myself. Those prices are on the same basis, and if the one is handed in it is right that the other should be handed in.

CUMBERLAND LAKES SCHEME.

SUMMARY of Estimate of Cost calculated on same Character of Work and same Prices as in Mr. Bateman's Estimate for the Welsh Scheme.

Reservoirs, lakes, and works of storage and collection		£1,013,000
Messrs. Hemans and Hassard's estimate is adopted.		
Aqueduct from Ullswater to Edgware:		
1st section from Ullswater to Ambleside (for particulars see below) 8 miles	£734,668	
2nd section from Ambleside to river Tame at Stockport (for particulars see below) 102 miles	7,040,625	
3rd section from river Tame, at Stockport, to Edgware (for particulars see below) 160 miles	7,962,500	
		15,737,793
		£16,750,793
The above estimate is on the assumption that 8ft. wrought-iron tubes are adopted. If 4ft. pipes were used, the extra cost would be 3,058,750*l.* (for particulars see below), or the total cost of the aqueduct from Ullswater to Edgware would be (15,737,793*l.* + 3,058,750*l.*)		18,796,543*l.*
Service reservoirs at Edgware and works for distributing water to existing centres of supply. This is assumed at the same estimated cost as for the Welsh scheme; but the lower level at which the Cumberland aqueduct is proposed to terminate will necessitate a larger outlay in the piping in consequence of the diminished head		2,179,121
Total		£18,929,914
If 4ft. pipes be used the total cost would be		£21,988,664

ESTIMATE of AQUEDUCT from ULLSWATER to LONDON

1st section from Ullswater to Ambleside, distance 8 miles, 2 miles open cutting, 6 miles tunnel (see Mr. Hassard's evidence, question 733).		
Open watercourse from lake to commencement of tunnel, 2 miles,—cutting 20 feet above conduit at the lake, and 50 feet at tunnel entrance, or 12 yards deep on the average.		
Excavation—at lake 90 cubic yards, per yard lineal, at tunnel entrance 400 cubic yards, per yard lineal, average 245 cubic yards at 1*s.* 6*d.* per cubic yard, including contending with water from river, &c.	£18 7 6	
Brickwork or stonework, 5⅔ cubic yards, 20*s.*	5 13 4	
Ashlar coping, 14½ cubic feet, 2*s.*	1 9 0	
Concrete, 4½ cubic yards, 10*s.*	2 5 0	
	£27 14 10	
Sundries	0 15 2	
Per lineal yard	£28 10 0	
1,760 lineal yards at 28*l.* 10 0,	£50,160 per mile.	
Bridges, drains, fencings, &c.	3,000	
	£53,160 per mile.	
2 miles at 53,160*l.* per mile		£106,320
Tunnel—area 240 square feet × 3 = $\frac{720}{27}$ = 26⅔ cubic yard, per lineal yard, say 27 cubic yards, per yard forward at 40*s.*, = 54*l.* per lineal yard, say 50*l.* per lineal yard or 88,000*l.* per mile. 6 miles at 88,000*l.* per mile		528,000
		£634,320
Contingencies, 15 per cent.	£95,148	100,348
		£734,668

2nd section from Ambleside to river Tame at Stockport, length 102 miles (see qq. 744—747).		
Covered aqueduct or tunnel, or aqueduct carried on substructure, or on arches, 24¾ miles (for section and detailed estimate see Appendix A S (1)) @ 50,000*l.* per mile		£1,237,500
Open aqueduct (for section and detailed estimate see Appendix A S (2)) 46½ miles at 35,000*l.* per mile		1,627,500
Syphon pipes, 3 lines of wrought-iron tubes, 8 feet diameter (for detailed estimate see below, and for section see Appendix A S (3)) 32¾ miles, at 127,500*l.* per mile		4,175,625
		£7,040,625
3rd section from river Tame at Stockport to Edgware, length 160 miles.		
Open aqueduct, same section as before, length, say half the whole distance, 80 miles, at 35,000*l.* per mile		£2,800,000
Syphon pipes, three lines as before, 8 ft. wrought-iron tubes, length from Tame at Stockport to five miles south	5 miles.	
Crossing of the Trent	10 „	
Total	15 „	
15 miles at 127,500*l.* per mile		£1,912,500
Covered aqueduct or tunnel, length, say remainder of distance, or 65 miles, at 50,000*l.* per mile		3,250,000
		£7,962,500

CUMBERLAND LAKES SCHEME.

PARTICULARS and estimate of proposed 8 feet wrought-iron tubes for syphons.

8 ft. tube with fall of 20 in. per mile will discharge about 82,000,000 gallons in 24 hours.

Area, 50·2656 s. ft., velocity 2·41 ft. per second.

Theoretical discharge		65,173,320 gallons per day.
Add 25 per cent. for difference between actual and theoretical discharge	16,293,330	„ „
	81,466,650	gallons per day.

Three lines of 8 feet tubes will be required to deliver 250,000,000 gallons in 24 hours, and average head of water on pipes assumed at 200 feet.

Estimate per lineal yard.

Wrought iron, 9/16 in. thick, weight per lineal yard, 2,966 lbs., say 23¾ cwt. at 18*l.* per ton	£21 7 6
Pipe trench, excavation for three lines, 60 cubic yards in a yard forward, or 20 cubic yards for each line at 1*s.* 6*d.* per cubic yard	1 10 0
	£22 17 6

1,760 lineal yards at 22*l.* 17*s.* 6*d.*
= £40,260 per mile for each tube.

5 per cent. for contingencies	2,013	„	„ „
Land	400	„	„ „
	£42,673	per mile for each tube.	

Say 42,500*l.* per mile.

3 lines at 42,500*l.* per mile £127,500 per mile.

Length of syphons:

From Ambleside to river Tame, at Stockport	32¾ miles.
From river Tame, at Stockport, to service reservoirs at Edgware	15 „
Total	47¾ miles.

J. F. Bateman, Esq.

11 March 1868.

CUMBERLAND LAKES SCHEME.

PARTICULARS and estimate of syphons, if 4 feet pipes adopted, as proposed by Mr. Bateman for his Welsh scheme.

4 ft. pipes, with fall of 20 ins. per mile, will discharge about 15,000,000 gallons in 24 hours.

Area, 12·5664 s. ft. Velocity, 1·74 ft. per second.

Theoretical discharge - -	11,763,658	gallons per day.
Add 25 per cent. for difference between actual and theoretical discharge - -	2,940,915	„ „
	14,704,573	gallons per day.

17 lines of 4 feet pipes will be required to convey 250,000,000 gallons daily, and average head of water assumed at 200 feet.

	Estimate per lineal yard.
4 feet pipe, 1⅜ in. thick, weight per lineal yard, 20 cwt., at 6*s.* per cwt. - -	£6 0 0
Laying and pointing, including excavating and refilling trench - - - -	0 15 0
	£6 15 0

1,760 lineal yards, at 6*l.* 15*s.* 0*d.* = 11,880*l.* per mile for each line of pipes.

Contingencies 5 per cent. - -	598	„ „ „
Total - -	£12,580	per mile for each line of pipes.

say 12,500*l.* per mile × 17 lines = 212,500*l.* per mile.

Length of syphons, 47¾ miles, at 212,500*l.* -£9,146,875

Cost of syphons, if 8 ft. wrought-iron tubes be adopted, 47¾ miles at 127,500*l.* - - - 6,088,125

Additional cost if 4 ft. pipes be used in place of 8 ft. wrought-iron tubes - - - -£3,058,750

6714. (*Sir B. Phillips.*) Your estimate for the Cumberland scheme to bring 250,000,000 gallons of water is in round figures 19,000,000*l.* ?—Yes.

6715. Messrs. Hemans and Hassard's estimate over the same ground for the same quantity of water is 11,670,000*l.* ?—Yes.

6716. In round figures there is a difference of 7,000,000*l.* as between the two ?—Yes.

6717. Do you suppose that the estimates of those gentlemen are insufficient to carry out the works efficiently ?—I have not gone into them, but I do not believe they are sufficient. As I say, I have not gone into them, but I have put both works upon the same basis, and if they can execute their works efficiently for 12,000,000*l.* I can execute the works from Wales for a much less sum than that which I have estimated my works will cost. No doubt the works could be made properly and satisfactorily if they were constructed upon a less expensive scale than that which I have proposed to introduce, but I do not think that any other mode than that which I have adopted should be adopted in dealing with a work of so much importance, which is to last for ever. If it had been my object to have said anything in favour of my own scheme I should have adopted a cheaper work and a lighter estimate, because I could have shown that in three or four years it would have been cheaper to have got water from Wales than to have pumped it from the Thames; but I have stated as clearly as I possibly could that I cannot consider that that is the mode in which the works ought to be executed.

6718. There is always a remarkable difference in the estimates for works of different descriptions; but this large difference between such eminent engineers as you are does appear to be something very unusual, because the one says that it will take 12,000,000*l.* to carry out certain works, and the other says, that in order to carry out the work efficiently in the way in which it ought to be done, it will take 19,000,000*l.*—I say that my estimate is based upon a certain class of work, and I think that that is the right class of work, and if the other is to be worked out on the same scale and the same class of work I estimate that it will cost 19,000,000*l.*

6719. (*Chairman.*) Supposing it be thought right to bring the water from Cumberland and not from Wales, you say that it ought to be brought in the same manner as you propose to bring it from Wales ?—Yes.

6720. And if it is brought from Cumberland in the same manner as you propose to bring it from Wales, it will cost 19,000,000*l.* instead of 12,000,000*l.* ?—Yes.

6721. But you do not mean to say that it cannot be brought from Cumberland in the manner which Mr. Hemans proposes for the prices which Mr. Hemans suggests ?—I have not said so; but if I were pressed I should say that his estimate was too low. I do not find fault with his estimate; I merely say that according to the determination of the strength of the pipes which would be required to bear the pressure that they must be subject to, and taking everything else at the same scale as I have applied to my own works, I estimate them at exactly the same prices.

6722. (*Sir J. Thwaites.*) Are we to understand you to state this, that without going into Mr. Hemans' estimate you have instituted a fair comparison because you have applied your own estimate to the works which are necessary for the purpose in your judgment to bring the water from the other district ?—That is what I have done. You cannot compare two things together until you get them put upon the same basis.

6723. (*Col. Harness.*) Does not the velocity differ in the two schemes ?—Yes.

6724. Would not that of itself involve a difference in the works ?—No, I think not, because the velocity is very small. The velocity in neither case is such as would be inconsistent with a simple clay bottom.

6725. What is your velocity ?—I think about a mile and a quarter or a mile and a half per hour, or between two and three feet per second. This is what the work must be and what they must do upon the same footing (*producing a section and explaining the same*). The velocity in my own case for conveying 230,000,000 gallons in the open aqueduct is 2·16 feet per second mean velocity. Their mean velocity for conveying 250,000,000 gallons is 1·82 feet per second, being 45 per cent. of difference.

6726. (*Sir J. Thwaites.*) Messrs. Hemans and Hassard have checked their velocity by dams, have they not ?—No, they have not, nor have they any occasion to do so. Of course stop-gates will have to be introduced here and there for the purpose of regulating the quantity of water which would be going down, but there would be no occasion if you were always discharging the same quantity to do that as far as mere velocity is concerned. A river runs on unchecked with a certain degree of velocity, and so this would run on with a certain degree of declivity as it does in Glasgow and Manchester, but of course dams would be introduced for the purpose of regulating the quantity.

6727. It might have an effect upon the cost of construction if you lessened the velocity, because you would construct your works with less solidity than you would if your velocity were increased ?—I was about to say that both these velocities are consistent with the open aqueduct being formed exactly as a simple canal with a clay bottom. It would not disturb a clay bottom, and it would not affect at all a gravel bottom. But then I do not think that that is a proper way to convey water for the supply of a city. You ought to have it lined through. I have adopted in my work because it was most expensive (and I did not want to do anything which might be construed to be in favour of myself) a lining of concrete with a facing of bricks, and I have put Mr Hemans' work upon the same footing. But where you go through a stone country you would adopt the stone of the country, and do it as cheaply as you could. There is not much difference between one country and another, in that respect, in proportion to their length; but in any case I think it should be lined through in such a way as that you can stop off a portion and cleanse it from all corrupt vegetable or other deposit, or for the purposes of any repair that you might wish to do from time

to time. This would be a work for all time in one case as in the other, and it ought to be as perfect as the sewers in London.

6728. They propose to line this, do they not, with native stone?—Yes. I should do so where I pass through a country in which stone would be yielded. They must be precisely the same in proportion to the length of the conduit. I have perhaps a larger district in which I can get native stone than they have, but there is nothing in that which can affect the comparative estimate.

6729. How do you account for the great difference of price?—That is all in detail in my tables. In the first place there is 100 miles difference, which in round numbers is 37,000*l.* or 38,000*l.* a mile, or 4,000,000*l.* sterling.

6730. Then structurally there would be about 3,000,000*l.* difference?—Yes; I have put stronger pipes than they have done.

6731. First of all they have 100 miles greater distance at so many thousand pounds per mile, which will give 4,000,000*l.*?—Yes, that alone would do it.

6732. And you have to make up the 7,000,000*l.*?—Yes.

6733. Then you have structurally to account for the 3,000,000*l.*?—Yes.

6734. Is that due to the substitution of wrought iron in their case?—To a considerable extent that is so, and also to the larger size of the aqueduct, and therefore it would be more costly. The Commission will see at once that this is the size of their covered aqueduct (*producing a section*), and this is the size of my covered aqueduct (*producing another section*). I have taken the same strength and dimensions for the large one as I have for the small one. If that is strong enough for them it is too strong for me, but if it is not strong enough for them, they ought to have added a little to it.

6735. I presume this would have to be varied according to the ground through which you were passing?—Yes, more or less. If you look at the other sections you will see that the aqueducts look very much larger and more costly than this, and the tunnels also must be in the same way. You will observe also that they have only 20 inches of fall for their syphon pipes, whereas in mine I have 5 feet of fall. All these things cause very great differences in the cost of construction. There is one other point which I cannot avoid mentioning, and that is the level at which they terminate near London. The level at which I propose to terminate, which is 270 feet above the Ordnance datum, enables me to construct those great reservoirs, which I had the honour of describing to the Commission the last time I was examined, in such a way, that I have a pressure head to carry the water to every one of the existing high-service reservoirs of the present companies, except those at two or three very high points. In consequence of their greater length, they terminate at such a level that they cannot for instance supply the Maiden Lane reservoir of the New River Company. Instead of having the amount of fall which I have, 5 or 6 or 8 or 9 feet in the mile, to some of these reservoirs, they have to come down to about 2 feet of fall in a mile, 232 feet being the level at which their aqueduct terminates.

6736. (*Mr. Harrison.*) Will you give the level of the discharge pipe from the reservoirs in both cases?—270 feet is the level at which I terminate. I have taken for the conduit to the Maiden Lane reservoir to supply the East end of London, a starting point of 250 feet, which is 20 feet below the level of the service reservoir. I have taken as a starting point for other parts in other districts, 262 feet 6 inches. I might have taken it at the top of the service reservoirs, because those would always be filled, but I have thrown away 7 feet 6 inches, and taken 262 feet 6 inches as a starting point at present to all those other points, and my calculations are based upon that. Messrs. Hemans and Hassard terminate at 232 feet, but then giving them the full advantage of the reservoir being always full, and taking the pressure from the full reservoir, they have 30 feet less than the pressure which I have taken. That has two effects; in the first place it is so low that they cannot avail themselves of the natural features of the country. At the foot of those hills there is a hollow and then the ground swells into breasts of hills, which are closed by embankments across the valley, at the level which I have adopted. They get 30 feet below that, and they get beyond those breasts into the open country where they cannot make their reservoirs so cheaply or so advantageously as the reservoirs which I have selected. Then they are at so low a level, that they cannot supply the Maiden Lane reservoir, and they can only get to the Kent district, if I remember rightly, with a fall of 2 feet per mile, whereas we get there with a fall of about 5 feet per mile, consequently they must have larger pipes. With a fall of 2 feet per mile, a 3 feet pipe will discharge perhaps about 5,000,000 gallons, whereas with a 5 feet fall per mile it will discharge nearly 10,000,000 gallons in 24 hours, so that you have to put two 3 feet pipes with a fall of 2 feet instead of one 3 feet pipe with a fall of 5 feet per mile in order to give the same quantity of water. So that there again is a great increase in the cost of the work, and at the same time you cannot give so high a pressure by 30 feet as you can by terminating at the level which I have adopted.

6737. (*Chairman.*) Will you now proceed to the next point to which you wish to call the attention of the Commission, which is the insufficiency of the supply of the water of the Thames in dry weather at Henley?—That is with regard to a scheme which has been proposed for bringing water from Medmenham to London. It is proposed by that project to bring 200,000,000 gallons a day, and there was evidence given by the gentleman who proposed that scheme as to the quantity of water which the river yielded. In his evidence upon the Metropolis Water Bills in 1851, Mr. Hawkesley described a scheme which he had for supplying London, and he mentioned this:—"At the latter end of the month of June last" (that is, in 1851,) "a short time before the termination "of the severe drought which had so long prevailed, "I measured the water flowing down the Thames "at Bray Lock, and I then ascertained that the "minimum discharge amounted to 200,000,000 "gallons per diem." Now, Bray Lock is 12 or 13 miles below the spot at which it was proposed to take the water at Medmenham; therefore, you could not get 200,000,000 gallons if this measurement be right, and this measurement agrees very nearly with my own measurement and with the evidence which has been given as to the quantity of water in the Thames at Hampton and Kingston. According to Mr. Hawksley's measurement in June 1851, the whole volume 12 miles below this point was but 200,000,000 gallons in dry weather at the end of the drought; and that corresponds with the measurements which have been given in evidence before the Commission with regard to lower points. Therefore, unless you left the whole bed of the Thames dry, which is not a thing to be done, that quantity of water could not be obtained. The fall proposed there is only 1 inch per mile, which gives a very slow velocity indeed for the purpose of delivering 200,000,000 gallons per day. Of course that amount of fall involves a very large area of conduit; indeed, it requires a conduit 40 feet wide and $12\frac{3}{4}$ feet deep, in order to carry 200,000,000 gallons a day; and it requires two covered channels 22 feet wide and 14 feet deep, in order to convey the water. I have taken that in the same way as in the other case, at the same scale of prices, and the same class of work as I have adopted in my own case.

6738. (*Sir J. Thwaites.*) What would the velocity be?—One foot per second. There is a portion of the work which I cannot very easily understand; that is canalizing the river above the point of diversion. I have only put down 100,000*l.* for the aqueduct over the river Thames at Maidenhead, and the whole of the works for canalizing the river above, which I do not

J. F. Bateman, Esq.

11 March 1868.

quite understand; but if it is at all equivalent to what is described it will cost a great deal more than 100,000*l.*, but putting it at that, the whole work comes to 1,932,000*l.*, and the water is brought in then only at the elevation of the Regent's Canal, about 100 feet above Ordnance datum. It then has to be lifted, and the cost attending that, with interest on the outlay, would be quite as much as that for lifting the water from the Thames, as the companies do now, and there is therefore no advantage and no saving at all, even if the water of the Thames at that place were sufficient for the purpose of abstraction. I have not thought it necessary to go into the analysis of any other schemes. Those are the more marked and more promising schemes which in my opinion have been brought before the Commission, and although there are many others I hardly think it is necessary to refer to them.

There is but one other point that I am desirous of laying before the Commission, and that is as to the financial result of the scheme which I have had the honour of describing. The pamphlet which is in your hands was written 2½ years ago, and everything has been increasing in point of population and demand for water since then. The rateable value of property within the metropolitan district in 1867 was upwards of 16,000,000*l.* per annum; 1*d.* in the pound upon that is equal to 67,000*l.* The probable assessable value by the time the works could be completed, say 1875, may be safely taken at 20,000,000*l.* sterling. Of this say 13,000,000*l.* will represent house property. The 20,000,000*l.* of course includes all property. If we assume a domestic rate of 10*d.* in the pound upon all the house property and 2*d.* in the pound upon all property for the public advantage to be derived from a work of this kind, the result would be as follows: 13,000,000*l.* per annum at 10*d.* in the pound would be 541,667*l.*, and 20,000,000*l.* at 2*d.* in the pound for the public rate would be 166,666*l.*, making a total from compulsory rates of 708,333*l.*, and then comes in addition the sale of water for trade purposes. When I wrote that pamphlet in 1865, although I believed from the knowledge which I had of other places that I had not overstated the amount which would be derived from those sources, which I stated at 250,000*l.*, I was under some apprehension that other people would think that I had materially overstated it, as it seemed so large a sum. In the evidence given before the committee on the East London Water Bill of last session all the companies gave the amount of water which had been sold in the year before for trade purposes and their various charges, and the total quantity of water sold for such purposes amounted in round numbers to 5,600,000,000 gallons. Their charges vary from 6*d.* to 9*d.* per 1,000 gallons, with 25 per cent. added for high service. Now, high service means in all cases except one the delivering of water at 10 feet above the ground floor of the house. High service in the New River case means 60 feet above Trinity high-water mark, and a very large proportion of the New River will be that, but in almost every case the water will be delivered by the other companies at more than 10 feet above the ground floor of the house so that to the ordinary charge 25 per cent. would have to be added. Now those are all charges by Act of Parliament from 6*d.* to 9*d.* per 1,000 gallons, with 25 per cent. added for high service. If I were to take it at 9*d.* per 1,000 gallons, which would be probably below the truth, it would come to 210,000*l.* a year upon the water which is now sold, and if you take it at 8*d.* per 1,000 gallons it is 186,660*l.* a year. But they charge a great deal more than either 8*d.* or 9*d.* I have here a report of the proceedings of the vestry of the parish of St. John, Hampstead, for 1867, and amongst other things it shows the price per 1,000 gallons at which the water was supplied, and the quantity in gallons, by the New River Company and the West Middlesex, and the price varies from 1*s.* per 1,000 gallons to 1*s.* 3*d.* per 1,000 gallons.

6739. Hampstead is at an exceptional elevation, and special pumping power is required. At all events the price is 1*s.* to 1*s.* 3*d.*, and they are not entitled to charge extra according to their Act of Parliament for anything but high service, which is 25 per cent., and that added to 9*d.* would be 1*s.*

6740. They are charging, are they not, in the districts of Wimbledon and Wandsworth 6*d.* per 1,000 gallons for extra high service?—That is very near their pumping stations; but if you take it at 8*d.* per 1,000 gallons, which would be about their lowest price, with 25 per cent. added for high service, it would come to 186,660*l.* a year. I have allowed in 1875 an increase upon that of about 50,000*l.* or 60,000*l.*, making a total of 250,000*l.* for the sale of water for trade purposes, and I am sure that that is below what the truth is, as it will actually be found. Then I have allowed for the sale of water to places on the way—10,000,000 gallons at 3*d.* per 1,000 gallons, which is a low price, and that is 45,000*l.* a year; and I have allowed for the sale of water to suburban districts beyond the metropolitan boundary, say 5,000,000 gallons at 6*d.* per 1,000 gallons; that is 45,000*l.* That is a low price, and those items come to a total of 1,048,333*l.*, assuming a domestic compulsory rate of 10*d.* and a domestic public rate of 2*d.* in the pound. Now as to the annual cost. In round numbers the cost, after deducting 1,000,000*l.* for available property, and adding interest and everything else which will accrue, so as to swell the cost before the introduction of the water, for 130,000,000 gallons, comes to 7,800,000*l.* The interest of that at 4 per cent. is 312,000*l.* The payment to the companies for existing dividends would be rather less, but I will put it at 500,000*l.*, and the cost of management 150,000*l.*, which is a large allowance, making a total of 962,000*l.*, showing a surplus of 86,333*l.* That surplus is equivalent to 1*d.* in the pound on the public rate, or 1½*d.* in the pound on the domestic rate, so that it shows that the people of London could be supplied after the expenditure of nearly 8,000,000*l.* with the softer water of Wales at 8½*d.*, for domestic supplies, and at 2*d.* for the public supply, making a total of 10½*d.*, or at 10*d.* for the domestic supply and 1*d.* for the public supply, making a total of 11*d.* in the pound. That is upon the rateable value, which I think is generally five-sixths of the actual rental. These rates are much lower than those charged for the supply of the hard water of the river Thames. The companies have a right to charge 1*s.* in the pound upon the full annual value, with extras for high service, for baths, for stables, and everything of that kind.

Metropolis Water Supply.

Statement showing Financial Results of obtaining Water from Wales, as on page 24 in pamphlet of November 1865, *revised March* 1868.

The total cost of the works on a scale, so far as the aqueduct is concerned, of 230,000,000 gallons per day, and reservoirs and pipes for the supply of 130,000,000 gallons, will be about 7,602,000*l.* To this must be added the cost of surveys, parliamentary expenses, interest on money during the construction of the work, the cost of superintendence, legal and general expenses, and these I estimate at about 1,083,000*l.*, by the time the works are completed, making a total of	£8,685,000
From this total I deduct the capital value of surplus property of the companies, to be released on the introduction of the supply by gravitation, estimated at	1,000,000
Leaving the net total	£7,685,000
The interest upon 7,685,000*l.*, or say 7,800,000*l.* at 4 per cent., is	£312,000
Add cost of management and working expenses, say	150,000
Payment of dividends to existing companies, and interest on their borrowed money	500,000
	£962,000

To meet these charges there would be received:—

Sales of water for trading purposes -	£250,000
Sales of water in bulk on line of aqueduct, and to suburban districts - -	90,000
Compulsory rate for *domestic supply*, at 10*d.* in the £ on 13,000000*l.* - -	541,667
Compulsory *public rate*, at 2*d.* in the £ on 20,000,000*l.* - - - - -	166,666
	£1,048,333

Surplus, 86,333*l.* = 1*d.* in the £ on £20,000,000

do. or 1½*d.* „ £13,000,000

6741. As I understand the calculation which you have now made, the result of a 10*d.* rate, and a 2*d.* rate, and the amount of water sold, would be about 1,000,000 and some odd pounds; what have you allowed for the invested capital of the companies?—500,000*l.* a year. I have taken their dividends. I do not remember exactly what their dividends were last year, but they are under 500,000*l.* a year. That includes the interest upon borrowed money and the dividends, which they divide amongst them. It is less than 500,000*l.* a year, but I have supposed that they were guaranteed the interest upon the money which they had borrowed, and the dividends which they now make, to the extent of 500,000*l.* a year.

6742. (*Mr. Harrison.*) Your calculation must also include all the expenses of maintenance and distribution?—Yes, it includes the expenses of maintenance and distribution, and the rates and taxes. The present rates and taxes come to about 40,000*l.* a year. I have allowed 80,000*l.* a year for rates and taxes. I have allowed 20,000*l.* for the outside administration, which is a very large allowance, and I have allowed 50,000*l.* for administration within the city itself.

6743. (*Sir J. Thwaites.*) Do your rates include the probable rating of your conduit and all your works?—Yes, I have ascertained what rating is paid in other places; but the rating is from returns made by the companies themselves and upon all that I have drawn the best conclusion I could.

6744. I am speaking of your conduit from the Severn; they would have a right to rate you in all the districts, would they not?—We should be liable to a certain amount of rate in gross and no more; and it would be divided along the line of country through which the conduit goes. It would be partly in respect of the water sold in London, partly in respect of the water obtained in Wales, and partly in respect of the water conveyed through the intervening districts; but you are only liable to the general rate which would represent the whole thing, therefore it would be spread over the whole district.

I have now come to the end of all that I wished to bring before the Commission, and I have only to thank you very much for the very kind and attentive manner in which you have listened to me. I may, perhaps, be allowed to say one word in conclusion with regard to the great advantage which I conceive would be conferred upon the inhabitants of London by the introduction of this superior soft water, and by the adoption of the principle which I have laid down, that the administration of the water should be in the hands of the inhabitants themselves, represented by a corporation or commission, or a board of works or board of health, for in my opinion it is as much the duty of the governing authorities to see that the poorest man has a good supply of water, as it is to see that the streets are paved and lighted, or that he has air to live in, for it is quite as essential to his comfort and his health. Everybody in a great community like this is dependent upon the supply of water brought to him. He cannot help himself unless he goes to a poisoned pump or to a neighbouring canal, or to the river Thames, and that only if he happened to be in close proximity. The example which was first set by the city of Manchester, and which has been followed by Glasgow and other places, of levying compulsory rates, has resulted in so much advantage and so great a benefit to the people at large, that I can only earnestly urge that particular view upon the Commission. I am led to make these observations, because his Grace asked me the other day whether it would not be possible to supply the existing companies with water which could be brought from Wales, and my answer was that it would be possible certainly, but that I had a very strong opinion against its being the proper mode of supplying the inhabitants, and my reasons are these. It is absolutely necessary that you shall have the means of levying compulsory rates. Water is as essential to people who live in a town as anything else. They must have it; they must either steal it or beg it, or get it in some way or other; and if they do not get it they are liable to disease and to other disadvantages which it is desirable to remove. You cannot give, or at least you never have given to any trading company the power of levying compulsory rates. You therefore make everybody pay as everybody ought to pay, and you get a large amount of income therefore without any individual hardship, and you are enabled upon the security of public rates of this character, to borrow your money at a lower rate than any private company could do. The average amount at which the money was borrowed by the Manchester Corporation for their water supply a couple of years ago, was 4*l.* 0*s.* 10*d.* per cent. The river Clyde trustees have recently been borrowing money at 3¾ per cent., and none of those great corporations at present are paying more than about 4 per cent. That is cheaper than the rates at which money could be obtained by any of the existing companies, and in the plan which I suggest you would pay nothing more than the interest of money borrowed at the lowest price and the working expenses.

J. F. Bateman, Esq.

11 March 1868.

6745. Can you state what is the form of the bond which enabled the Clyde trustees to borrow at 3¾ per cent.?—I cannot state that; but I was in Glasgow the other day, and the river Clyde trustees had just borrowed a considerable sum of money, I forget what it was, at 3¾ per cent. I am not sure whether the waterworks have borrowed at less than 4 per cent., but under their Water Act they have borrowed all their money, and I believe they do not pay more than 4 per cent. for it.

6746. Do they give in security the public rate, which they are authorized to levy?—Yes, the compulsory rates.

6747. (*Chairman.*) The money is borrowed in Glasgow at a varying rate probably?—They borrow from time to time as they require it, and of course at the price at which money happens to be at the time.

6748. It is frequently the case in Scotland, is it not, that if you borrow money you borrow it say at 4 per cent., and you afterwards pay interest varying as the Bank rate varies, and that is decided in Edinburgh?—I do not think that in this particular case it would be so. It would be at a certain rate for a limited period, for three years or five years, or something of that sort. I have here the Glasgow Corporation Waterworks return for the year ending May 1867, and I find that the loans on mortgage amount to 1,119,000*l.*, and the interest is 40,413*l.*, so that it is rather under 4 per cent. upon the whole amount of capital borrowed for the Glasgow waterworks. By my suggestion you would have further the advantage of constant supply at high service, and although I believe it would require some additional supply of water to that which is now taken, the consumption would be brought within narrower limits by proper supervision, and in any case it is the right mode in which the water ought to be distributed, and one which it has been impossible as yet to obtain from the existing companies. Those are all advantages which I think must be fairly taken into account even if the financial statement were against the introduction of the soft water, but as I have shown, you would by getting compulsory rates be enabled to obtain a supply of water of this superior quality, spending 8,000,000*l.* upon it, for a less charge per annum per individual than that at which it is now supplied by the existing companies.

The witness withdrew.

W. Rendle, Esq.

11 March 1868.

WILLIAM RENDLE, Esq., examined.

6749. (*Sir J. Thwaites.*) You are a surgeon, are you not, practising in Newington Causeway?—Yes.

6750. I believe you have held office in the parish of St. George the Martyr, Southwark, as medical adviser to the vestry?—Yes, I was medical officer to the parish for 17 years up to 1856, and medical officer of health during the three years after that: since that time, with little interruption, I have been a member of the vestry.

6751. During the discharge of those duties your attention has been called to the question of the deficiency of the water supply in that district, has it not?—Yes, frequently.

6752. Will you state to the Commission the result of those observations?—As to the deficiency of water, I believe it to be chiefly applicable to the supply as being intermittent. Complaints are numerous and incessant at our vestry, and our officers frequently note many places where complaints might be made, but are not, where the supply is deficient or altogether absent. The average quantity of water supplied to the people of London seems to be about 30 gallons per head per day, but that statement is extremely deceptive, for the class of people among whom disease usually begins, and upon whom it most heavily presses, do not get on the average—if I may take my parish as an example—more than from two and a half to five and six and seven gallons per head per day, and there is great waste. In my parish, which I give as a fair specimen of poor parishes, we have about 7,800 houses; of these 7,800 houses, 4,800 are houses which have usually been compounded for, and are occupied by persons of whom, perhaps, one half occupy only one room; the remainder of these 4,800 houses would be inhabited by persons occupying perhaps two rooms, but rarely more. These people are supplied, for the most part, with water to a not much larger extent than from three to four gallons per head per day. In order to bring pressure to bear upon the vestry to look into this and other matters, a circular was published, a copy of which I have before me. It was circulated among the vestrymen, and this is a paragraph contained in the circular. The vestry said in their agenda paper for that evening, "That the vestry "upon the recommendation of the sanitary committee "has in numerous instances ordered an increase and "better supply of water." My answer to that was "that 96 places had been visited by one of our chair- "men, Mr. Pocock, and myself during one afternoon, "when we went straight across the parish in the worst "parts without selection. We visited in all 96 houses, "and this was the result touching the water question. "Of the 96 places visited 42 require the inspector; "some are without any water supply, some without "water receptacles, some have broken or rotten "receptacles. All the houses, with two or three ex- "ceptions, are without covers to their butts, and so, "as one woman said, 'every bit of dust and dirt comes "in.' These, if cleansed, would become filthy "immediately from the foul atmosphere in these "close, filthy places; from drains and dungheaps close "at hand; from refuse, rags and dead animals wan- "tonly thrown by children into the open butts. In two "cases the small open casks were standing in pools "of liquid night-soil. In a very large number "the supply was quite insufficient. 15 houses with "181 inhabitants had water receptacles holding 456 "gallons—2½ gallons to each person. Pork tierces, "butter casks, small washing tubs, jars, and rotten "kilderkins, seemed to be the rule, except one side "of a street where no receptacles at all were found for "the people. An agent in St. George's New Town "(the chief fever haunt) says, 'There is not nor has "'been a sufficient supply of water about here; when it "'comes on, it generally dribbles and does not run "'in a full stream, and all the butts are too small for "'so many people.' With two or three gallons of "water it is of course impossible to keep house and "closets clean. The testimony of the people them- "selves ran thus:" One person said, "Our butt is so "rotten the water runs out as fast as it runs in." Another said, "We are obliged to beg water." Another said, "We are half the time without water." Others, "We have to go begging on Sundays." "We have only a nine gallon cask; we beg water "where we can." "I gave 6*d.* for my butt when I "came in four years ago." "We never had a butt "these five years." "We have no water, we beg it." And one said she "had hardly enough water to keep "herself clean with." These are a few of the many expressions we heard in our visit, given by the people in their own way. The water is on generally a very short time, 20 or 30 minutes, or, at the utmost, 40 minutes. The pipes are usually too small, or small ferules are introduced here and there underground into larger pipes, so as purposely to limit the supply. There is altogether too small a supply, and it has generally been most deficient where it is most wanted, that is to say, among people who are living in some parts of our parish 400 to the acre, or in other parts from 200 to 300 to the acre closely packed together. They do not get anything like water enough, and the modes of supply, the pipes, butts, in fact everything, are as a rule utterly insufficient for the purpose. In most cases there is only a small cask to receive the water; generally if there is a cask it is a very bad one, and in many cases there is none at all; there was one whole side of a street I recollect in my inspection in which they took the water from the tap; there was scarcely any yard, and the people had to keep their drinking water in basins underneath the bed or in one corner of the living room. That was in cases where the people occupied only one room. On Sunday the supply in our parish is altogether absent, or not worth speaking of. I understand that at this time, after a little pressure has been brought to bear upon the companies, there are about 8, 10, or 12 of our little courts which are supplied with water on Sundays; but it all comes through public taps, and does not go to the houses. I recollect some two years ago there was a very great outcry in Kent Street that the people were occupied half the Sunday (several Sundays) in going about begging water of their neighbours; many of the people said they usually got it at the public-houses; those who were near public-houses would probably get it from this source. The inspectors of lodging-houses, although they have more power than we have under their Police Act, to this very time frequently complain that they do not get sufficient water for the purposes of cleanliness in the ordinary common lodging-houses. As to the general supply, we have no complaints generally in connexion with the Lambeth Company; but against the Southwark and Vauxhall Company we are very frequently receiving complaints, not only as regards the intermittent supply, which is even at the times appointed for supply every now and then, as I am informed, altogether absent. Even in matters in which the company is bound to supply us constantly, as, for instance, in the hydrants that we water the roads from, and in the water waste preventers that we put up to prevent waste, and to afford constant supply in small courts, we and the poor people are frequently without water altogether. I understand from the evidence of our officers also, that when the large pipes, the mains I suppose, are empty of water, it is a very common thing for gas to get into the pipes and so to render impure the water which comes on afterwards.

6753. I understand your first complaint is that a very large number of poor people are insufficiently supplied with water, partly from the intermittent system which exists in the district and partly from the insufficiency of storage accommodation in the several houses?—Yes.

6754. You have spoken of casks and other receptacles; have you found that those casks or other vessels for holding water have been placed in a position near to closets where the water is likely to absorb any gases

which may be generated in cesspools and other places of that description, and is therefore likely injuriously to affect the health of the inhabitants?—In a district like ours, where in many cases the people have scarcely a back yard at all, where the houses are not quite back to back, but very nearly so, it is impossible, I believe, whether the casks are covered or not, but ours are mostly uncovered, so to place them that the water can be stored and be wholesome or even safe. I do not know whether the evidence has been before you, but in order to make it very clear and to show the power and danger of absorption by water that is stored in places where the atmosphere is unwholesome, I hand in a paper showing the usual absorbing power that water has in relation to certain gases. I may say that I gave this evidence in a printed report which I was requested to make to our vestry, which report I will hand in presently. I have corrected it up to the present time through my friend Dr. Odling; he writes me thus: "I send you the determinations of Bunsen, "which are considered to be most trustworthy." "1,000 volumes of pure water at mean temperature "dissolve 30 volumes of oxygen, 15 volumes of nitro- "gen, 3,232 volumes of sulphuretted hydrogen." This is a sewer and privy gas which we consider productive of fever, and which we can smell on entering many of the poorer places. I have tested this frequently by exposing a lead paper, which I have found darkened, proving the presence of sulphuretted hydrogen gas in the back yards. The water there stored will dissolve this gas in the proportion noted: "1,000 volumes of water will also dissolve "1,000 volumes of carbonic acid, and 782,700 volumes "of ammonia." Ammonia is principally a product of animal decomposition, developed in urinals and like places. This all indicates how dangerous the present state of things is in districts inhabited by very poor people, who are more or less filthy, partly from their own fault and partly because they have not the means and appliances for the storage of water; and it shows that water, when stored in such districts, cannot by any means of storage that you can devise be held to be safe as drinking water.

6755. Do you arrive at the conclusion that even if the vessels and receptacles were improved, it would not be safe to store water for domestic purposes, and that a constant supply under high pressure is the only remedy for that state of things?—I am satisfied as far as I can be certain of anything, that whatever it may be for the rich, who have comparatively large areas and paved court-yards and areas, and cleanliness in their houses, with fair means of ventilation about them, I believe it to be absolutely impossible for a large number of people in the poorer parishes of London to have wholesome water, if they are allowed the means of storage of any sort. In my parish there are 30,000 people in the poorest condition; they have hardly any back yards, and where they have back yards they are rarely paved, but are sodden and filthy with the soil running about; in some there are no dust-bins, the refuse being scattered about, moreover the houses are built much too close together, so that they have, except in case of storms, no sanitary draughts of air cleansing them out thoroughly.

6756. (*Sir B. Phillips.*) What would you suggest should be their means of supply?—Without any doubt they should have a constant supply of water.

6757. Do you mean by a standcock?—No, I think that mode is bad in every way, because the people would have to fetch the water, and there would be no supply in their houses.

6758. I understand you to say that it is impossible under existing circumstances for them to store water?—I do not calculate upon its being stored at all in vessels or cisterns or tubs, but that it should be brought by a tap into every house. I saw something like to this upon the property of Mr. Quick, the engineer of the Southwark and Vauxhall Waterworks. After he had published a circular and sent it to one of our vestries, as to the impossibility of having a constant supply among poor people, because they would waste it and misuse it, three or four vestrymen, myself included, inspected our own parish and other parishes in London, to observe what had already been done in the matter of a constant supply. This inspection is reported, pp. 11 and 12, Report on Constant Water Supply, written by me for and adopted by the parish of St. George's, Southwark, handed in. We found one court in our own parish near the Queen's Bench, belonging as I understood, and still understand, to Mr. Quick, where 16 houses were supplied upon the constant system, and had been so for seven years. The people there assured me that, excepting for a temporary purpose, such as cleansing the pipes or for repairs, they had never been without water night or day for about seven years. There was no particular waste going on; no water was laid on to the waterclosets, but nevertheless the waterclosets were cleaner than in places where it was supplied to them direct. The water in this court was turned on mostly by a screw tap from a pipe running behind the houses; it was one of the best conducted courts we had, which seemed to prove that the poor people took care of the water and valued it.

6759. (*Sir J. Thwaites.*) Have you turned your attention to the effect of soft as compared with hard water upon the health of the people?—I do not think that I can give direct evidence upon that point. I think the injury from hard water, undoubted I believe, is rather indirect; in the first place you cannot cleanse the body so well, the cleansing action of the soap is more or less defeated; the skin is covered with a greasy deposit from the decomposition of the soap. It is the same with regard to clothes: you cannot cleanse them nearly so well even if you use soap freely. There is another evil which can scarcely be over-estimated, you cannot cook so well; it is moreover not so economical in cooking. If you try to make a cup of tea with soft water and a cup of tea with hard water, you will find that your tea is not nearly so well worth drinking made with hard water as when made with soft. This of course is indirect evidence. However, I think it will answer the question just as well as if it were direct, because the same results come out, namely, incomplete cleanliness and bad cookery, and that these must be injurious to health is evident to all.

6760. (*Mr. Prestwich.*) Are there any public water taps in your district?—We have two water-waste preventers which the vestry has erected for the good of two of our filthiest courts; they are in pretty good action, and we have in some of the courts public taps, but these contrivances are at the best not much better than makeshifts.

6761. But they are not in general use?—No, they are not in general use.

The witness withdrew.

Adjourned to to-morrow at 12 o'clock.

Thursday, 12th March 1868.

PRESENT:

SIR JOHN THWAITES IN THE CHAIR.

Sir BENJAMIN PHILLIPS.	THOMAS ELLIOT HARRISON, Esq.
Colonel HARNESS, C.B.	JOSEPH PRESTWICH, Esq.

S. C. Homersham, Esq.

12 March 1868.

SAMUEL COLLETT HOMERSHAM, Esq., examined.

6762. (*Chairman.*) You are a civil engineer?—I am.

6763. Have you specially directed your attention to Dr. Clark's process as a means of softening hard waters?—Yes, I have specially directed my attention to procuring spring water from the chalk, that spring water from the chalk being softened by Dr. Clark's process before it is supplied to the consumers.

6764. Can you shortly state to us the process of Dr. Clark for softening water, and then the steps which you have taken to apply it, and where, and what has been the result?—The process is simply putting a certain quantity of water saturated with lime into a reservoir. If the reservoir holds 900,000 gallons of water, in the first instance you put in the bottom of the reservoir 100,000 gallons of saturated lime water, and then add to this 100,000 gallons of lime water 800,000 gallons of spring water; I say spring water because it is essential for the process that it should be a clear spring water; a river water is not adapted for being softened by the process.

6765. Are we to understand that the lime water which you apply is in bulk as one to nine?—Yes, one-eighth to one-ninth in round numbers, sometimes it is a little more and sometimes a little less, according to the quality of the water, but as a rule about one-ninth is the average quantity required. The reservoir is then filled up with spring water, say eight-ninths of it, and the water as it is sent in to fill up the reservoir is sent in at a low point through three or four small apertures at a considerable velocity, so as to mix the lime water and the spring water intimately together; when the reservoir is filled the water is allowed to stand something like five or six hours, a sufficient length of time for the carbonate of lime that is formed by putting the lime water to the spring water to be deposited, and the water then becomes perfectly clear. The water when clear is either lowered into a reservoir situated below the reservoir in which it is softened, or if the water has to be delivered at a higher level it is pumped up to a reservoir at a higher level for the supply of the consumers.

6766. What time is occupied in mixing the lime water one-ninth in bulk with the water in the reservoir?—To give a practical illustration; at the last works which I recently made in the Chiltern Hills, we soften in one reservoir 100,000 gallons of water. The lime water is put in in half an hour, and the hard water is filled up in about three hours, making three hours and a half, and at the end of six or seven hours after that the water is clear, and ready to lower down into the reservoir below; so that altogether the softening in one reservoir takes some nine or ten hours. If the quantity be 1,000,000 or 10,000,000 gallons it is just the same, supposing your engine power to be as adequate to pump the larger quantity of water, as it would to pump the smaller quantity.

6767. Will you now state where you have applied this process, and with what success?—The process has been applied at various works. It was applied at the Plumstead works, which were opened in 1854, and the process was in operation there for seven years and gave great satisfaction.

6768. Is it in operation now?—Not at the Plumstead works; it was in operation there till 1861, when the works were sold to the Kent Water Company, and immediately upon the Kent Water Company purchasing the works they ceased to soften the water. It was not because the process did not answer, and it was very much against the wish of the consumers who were supplied with the softened water, but they did as a matter of fact cease to soften immediately they purchased the works. The Plumstead works were made, I should say, in opposition to the Kent Water Company, and they were in operation for seven years in opposition to them. They were then sold to the Kent Water Company, and when the Kent Water Company got possession of them, and not before, the softening process was abandoned.

6769. Are you informed as to the motives of the Kent Water Company in giving up this process?—No, it is impossible for me to be certain as to their motives. I know the engineer of the Kent Water Company, Mr. Morris, very well, and I understood at the time that they gave up the process simply because they did not choose to apply it through their whole district. The Kent Company supply a very large district independent of the district which they supplied when they bought the Plumstead Company, and they gave up softening, but of course I cannot tell with certainty what may have been their motive.

6770. What was the volume of water operated upon at Plumstead?—At Plumstead, latterly, we operated upon just about 1,000,000 gallons a day. I think from 900,000 to 1,000,000 gallons. In summer we frequently softened as much as 1,000,000 gallons.

6771. What was the size of your reservoir?—There were three reservoirs there, each holding 220,000 gallons, independent of the room below for the deposit. We could soften in each reservoir about 220,000 gallons, the reservoir holding about 250,000 or 260,000 gallons, the extra room being required to allow the carbonate of lime to deposit at the bottom of the reservoir.

6772. If your reservoir accommodation did not exceed 660,000 gallons, it would take you 15 hours to soften that quantity, would it not?—I will explain the process. Here are plans and sections of the three Plumstead reservoirs (*producing the same*). The spring water is pumped into a reservoir, the lime water being at the bottom of the reservoir. In this first work at Plumstead we used cream of lime instead of lime water; in all other works which I have made we use lime water. We made cream of lime the same as lime is slaked for whiting the ceiling; the cream of lime was forced by means of a cylinder among the water as the water was pumped up from the well; the lime mixed with the water, and then passed through what we call an agitator or a mixing apparatus (*producing a section*). The cream of lime and water, at the rate of about 1,000 gallons per minute, was forced together through a pipe, enlarged for a short distance, and having four plates with small holes in it. The cream of lime with the water went through the holes at a higher velocity than it did in the body of the pipe. Then it went on through another such agitator, and so into three agitators. The water then passed by means of a pipe into a catch reservoir, and any bit of flint or any small matter that might have mixed with the lime fell to the bottom of this catch reservoir. The water then proceeded on to another agitator, and finally went into the depositing reservoir.

6773. That process of dealing with a certain quantity of water, mixing it with one-ninth its bulk of lime, water agitating the water, and passing it into the reservoir occupies about 10 hours, does it not?—The filling of the first reservoir occupies about three hours and a half, and as soon as that is filled the second reservoir is filled.

6774. Then from the commencement of the operation, having your plant all ready, mixing your lime and then passing it into this pipe and through the agitator, so as thoroughly to mix it with the large body of water, and allowing the deposit to take place, and passing it into the reservoir, it occupies how many hours?—As soon as we had filled the first reservoir, and while we were filling the first reservoir we were intent on pumping the softened water from the second reservoir into the service reservoir, which was situated on Plumstead Common at an elevation of 170 or 180 feet above the works, and by the time the No. 1 reservoir was filled No. 2 reservoir was empty. We then filled up No. 2 reservoir, and at the same time emptied No. 3 reservoir, and by the time No. 2 reservoir was filled, No. 3 reservoir was empty, and by the time No. 3 reservoir was filled No. 1 reservoir was emptied, and ready to fill again.

6775. Those three reservoirs were found sufficient for dealing with 1,000,000 gallons?—Rather more than 1,000,000 gallons, but practically they supplied about 1,000,000 gallons a day of 24 hours.

6776. Supposing you had to deal with a larger body of water, are those reservoirs of a size that you would use, or would you increase the size of the reservoirs to adapt them to the larger quantity?—If I were dealing with 8,000,000 or 10,000,000 or 12,000,000 gallons of water a day I should certainly have an additional number of those reservoirs, or reservoirs of larger capacity.

6777. Would you multiply the reservoirs or increase their capacity?—I should increase their capacity; in the first instance I should make them very much larger, and the engine power would also be very much more powerful, but we should fill them relatively in the same time.

6778. Still keeping to the works at Plumstead, where you had experience for seven years, can you tell us what the cost of the application of this system of softening was?—Yes, I can tell it quite accurately. The total cost of the construction of those three depositing reservoirs, the lime apparatus, and the whole complete, was under 3,800*l.*, including the connexion with the pipes, the agitators, and so on.

6779. Do you mean that that was the cost of all the arrangements necessary for your softening process?—Yes, except in this, that we pumped the water from a well about 150 feet deep to the bottom of the well, and if we had supplied the water in its normal condition in its hard state to the consumer we should only have had one set of pumps, and should have pumped the water direct from the well to the service reservoir upon Plumstead Common, and that would have saved us some little expense in the first cost. To soften the water we had two sets of pumps. We had one set of pumps at the well which pumped the water into the softening reservoirs, and we had another set of pumps to pump the water from the softening reservoirs to the service reservoirs, from which it was supplied to the consumers, and as nearly as I can say that might have cost an extra sum of 500*l.* or 600*l.*

6780. That would be 600*l.* added to 3,800*l.*?—Yes, including the extra pump work.

6781. Is that an inclusive sum, or are there any other items of cost?—No, I think that is fairly the cost at those works. You will observe that the softening reservoirs are not covered. Now from my experience at those works I have never made any other works with softening reservoirs uncovered, and I should not recommend the water to be softened in uncovered reservoirs. It is quite as practicable to soften in uncovered reservoirs, as it is to filter in uncovered reservoirs, but pure spring water is of a very delicate character, and in hot weather many sorts of things settle upon the top of the water.

6782. What would be the cost of covering reservoirs of this size?—Those reservoirs would probably cost another 1,000*l.* additional to cover.

6783. Then about 5,500*l.* would be the total cost?—Yes, I should say if you calculate it at 6,000*l.* per 1,000,000 gallons, that would be the outside estimate for the structural works. I may also add with regard to filtering river water, that the structural works would have cost as much as those reservoirs, and as far as the pumping goes, you must take the water from the river, and pump up your water after it has been filtered.

6784. Will you direct your attention to the cost of working and the current expenses?—The current expenses at Plumstead were about 1*l.* 7*s.* per 1,000,000 gallons, for the cost of the lime and the labour, that is to say, the cost of the lime was about 1*l.* per 1,000,000 gallons, and the labour about 7*s.*, making about 1*l.* 7*s.* as the cost of the lime and the labour per 1,000,000 gallons.

6785. But there are other expenses besides the labour and lime, are there not?—I think not, the pumping is included, because although we pump from the well into the softening reservoir, and then we pump from the reservoir into the service reservoir, yet the total lift is no more. We raise water from the well, say 130 or 140 feet into the softening reservoirs, and then we raise it from the reservoirs another 150 or 160 feet into a service reservoir situated on Plumstead Common, but if not softened we should have had to raise it at once 300 feet.

6786. You move your agitator by means of steam, do you not?—Yes, but that is a very small matter. I think that the 1*l.* 7*s.* would quite include it; it is nothing of any consequence.

6787. Have you been able to form an opinion as to the application of this system to 1,000,000 gallons, or its application to a very much larger volume of water?—If you take spring water, which, as I have said before, is essential to the success of this process, you may apply it to any amount of water. It is much easier to apply it to 100,000,000 gallons a day than it would be to 1,000,000 gallons a day, inasmuch as the adjustment of the exact quantity of lime to the water is much more easily accomplished on a very large scale than on a small scale.

6788. Taking the supply to the metropolis as 100,000,000 gallons a day, have you formed any idea as to the cost of the works which would be suitable for dealing with so large an amount of water?—Taking 6,000*l.*, which I am sure is an outside estimate for the works to soften 1,000,000 gallons, of course it would be 600,000*l.* for the whole metropolis, at 100,000,000 gallons a day.

6789. What would be the area which you would require to carry out this system?—I have not calculated the area; I could do so; it is nothing very large; the works for that 1,000,000 gallons a day covered about a quarter of an acre. I should certainly say less than one-third of an acre, or perhaps say about one-third of an acre. Of course that is for 1,000,000 gallons, and that would be 3,000,000 gallons to the acre, or about 33 acres for 100,000,000.

6790. Have you calculated the cost of applying this system to the whole of the supply of London?—The cost would not be more than what I have given; on a large scale probably you may do it more cheaply rather than less cheaply, so that you may take 600,000*l.* as the cost of the structural works; the cost of lime and labour per 1,000,000 gallons would be 1*l.* 7*s.*

6791. Mr. Morris was examined here as a witness, and he states with reference to Dr. Clark's process at Plumstead, that he took possession of the Plumstead Works, where the process had been going on for some years, but he says, "We did not carry it on; we "found the whole thing so imperfect and so utterly "not to be depended upon, that we were obliged to "abandon it?"—I would say in answer to that, re-

S. C. Homersham, Esq.

12 March 1868.

siding as I did at Shooter's Hill at the time those works were under my charge, and having my attention specially directed to the works which, as I said, was for a period of seven years, that immediately the works came into the possession of the Kent Company they ceased to soften by that process, and they had no experience with it at all. Mr. Morris did not carry on the softening process for one hour, and therefore it is not correct for him to say that the process was troublesome, and that that was the reason he abandoned it.

6792. He says here that all the leaden cisterns in the district of Plumstead were found to be seriously affected, and some of them perfectly destroyed?—That is altogether erroneous. The softened water has far less action upon lead than the unsoftened water; softened water in fact has no action at all upon lead, and the unsoftened water may have a very slight action. I hold in my hand a report by the late Dr. Clark and by Dr. Smith, who both examined this point very carefully indeed, and this evidence of Dr. Clark's and Dr. Smith's was confirmed by Dr. Stenhouse, by Dr. Lankester, Mr. Dugald Campbell, and some other equally eminent men. What they state is this: "In order to ascertain whether the softened "spring water would take up any dangerous quantity of "metal from leaden pipes or cisterns, we kept this "water in contact with lead under precisely the same "circumstances as four other waters that were not "known from experience to have produced upon the "consumers any ill effects from lead. The contact "was continued long enough to permit a considerable "action by some of the waters. Of those tried, the "water that had most action on lead was the filtered "water of the river Dee, as supplied to the inhabi-"tants of Aberdeen. This water, which is about "half the hardness of the softened Watford water, "and contains about half the saline matter, took up "one-tenth of a grain of lead per gallon. The next "degree of action on lead was found in the Thames "water; one specimen from the West Middlesex "Company's water, another from the Lambeth Com-"pany's water, derived by them from Thames Ditton. "There was no perceptible difference in the action of "these waters upon lead. Each took up about a "half of the preceding water, or one-twentieth of a "grain per gallon. Next in its action on lead was "the New River water, which took up two-thirds of "what the Thames water took up, or one-thirtieth of "a grain per gallon. Tried in precisely the same "way as the Dee, the Thames, and the New River "waters, the softened Watford water showed to our "tests no action on lead, although those tests would "have detected in the water much less than one-"hundredth of a grain per gallon." I may state practically that I made the works as I said for the supply of Castle Howard with softened water, which have been in operation for a great many years. The water is pumped by a water-wheel for the supply of Castle Howard through a lead pipe, which is laid all the way up from the works, which are something like half a mile distant to the castle, and the cistern itself is lined with lead. It is a very large cistern, perhaps half as large as this room, and there has not been the slightest action either upon the lead pipes or upon the cistern. I was at the works a very short time ago, indeed within the last fortnight, and there is not the slightest action upon the cistern or upon the pipe. The late Earl of Carlisle, who took a great interest in the softening process (and it was through him that it was adopted at Castle Howard), had the water constantly examined when the works were first in operation to see if there was any action upon the lead by the water, so that nobody might be injured at the castle.

6793. Can you point us to any other place where this system has been applied to any considerable quantity of water?—The works where they are applied I can give you in order. There was the Castle Howard Waterworks, opened in 1858. Then there were the Caterham Waterworks.

6794. Of the latter I believe you have no experience at present?—They have been in operation ever since 1861, so that we have seven years' experience at Caterham, and we have added within the last twelve months 20 miles of pipe to that district.

6795. What is the amount which you supply from those works?—We supply Caterham, Godstone, Bletchingley, Nutfield, and Red Hill, a district containing a population of 24,000 persons.

6796. What quantity are you supplying now?—I do not know the exact quantity at the present time, but only last autumn our pipes were extended into Red Hill, and the works have been in use for the supply of Caterham, and Warlingham, and a large district around, ever since 1861. I do not know the exact quantity that we are softening per day. There we have no complaints, and in fact I may say positively that there is no action of that water upon lead. I have a report by Mr. Campbell, who has analysed that water most particularly for its action upon lead, and in it he states: "The action of the "softened water was tried in a very severe manner, "by exposing it for six days to bright scraped lead, "and likewise to ordinary lead, such as in pipes and "cisterns, only in each experiment the surface of "lead exposed was very much larger indeed than "would occur in practice; and on testing the water "afterwards by the most delicate tests I was unable "to detect a trace of that metal in either case, so "that this water may be said practically to have no "action whatever upon lead, which is not the case "even with many hard waters, although their action "is generally slight, and scarcely what may be termed "of a deleterious nature." We have practically supplied it to cisterns in Caterham lined with lead, and we find not the slightest action upon lead by that water.

6797. But you have made no calculation at all, have you, as to the cost of the works for dealing with the whole water supply of the metropolis, or as to the annual charge for working the system?—I have already said that 600,000*l.* would be the cost of the structural works, and that 1*l.* 7*s.* per 1,000,000 gallons would be the cost of softening the water, it might be rather less upon a larger scale.

6798. Are you sanguine as to the applicability of this system to the whole supply of the metropolis?—Certainly, there is no more reason why water should not be softened than that it should not be filtered, it is easier to soften water; I have had a great deal of experience in filtering water, and a great deal of experience in softening water.

6799. What do you do with the spent lime?—I have brought some of the deposit to show the Commission. We put in half a ton of lime and we take out in return 3½ tons of whiting, the most beautiful whiting you can possibly imagine. If you put it under a microscope you will perceive that it forms beautiful octohedral crystals perfectly white, and it is well adapted for cleaning metals, making soda-water, and most of the purposes to which ordinary whiting is applied; and if the process is applied in covered reservoirs, and proper care is taken with the whiting, I have no doubt that it will pay a very large proportion of the expense of the softening process itself.

6799*a*. Have you had it analysed?—Yes, I have had it analysed, and I have the analysis of it here. This (*producing a specimen*) is some whiting taken within the last day or two from the Chiltern Hills works. That is made not with cream of lime, but with lime water.

6800. Then it has been no source of expense to you but rather of profit to utilise this product?—I should say that the commercial value of that whiting is about 15*s.* or 16*s.* a ton, and I calculate that the value of the whiting would be equal to the whole cost of softening the water. Here is the analysis of the whiting by Mr. Campbell:—

"I beg leave to report to you the results of my analysis of a specimen marked 'The Caterham Spring Water Com-

pany. Whiting or precipitated chalk obtained in softening the water by Dr. Clark's process, December 10th, 1863.'

	In 100 parts.
Moisture	5·39
Silica	1·09
Oxide of iron, alumina, and phosphoric acid	0·94
Carbonic acid	40·39
Lime	49·40
Magnesia	1·50
Potash	0·49
Soda	0·74
Loss	0·06
	100·00

was submitted to low redness for some hours, but without any loss of weight, thus showing that it contained no organic matter; but besides this test the gas was passed for hours through proper solutions, to test for organic matters, but without exhibiting the slightest trace. This, together with the high per-centage of carbonic acid which it yields, would render it, I think, especially valuable for the manufacture of gaseous drinks."

6801. (*Mr. Prestwich.*) What do you consider to be the value of this whiting?—I consider it worth from 15*s.* to 16*s.* a ton. We have never sold it for so much, because it has never been worth our while to collect it in a proper manner, and put it before the public for sale. At Plumstead we used to sell the whiting for about 7*s.* a ton, but it was used by brickmakers. There was a great demand at Plumstead at the time those works were in operation for chalk to mix with brick earth for making bricks, and we used to get rid of it without drying it; men came and fetched it away at 7*s.* a ton, and that about paid for the lime. For every ton of lime that we put in, we took out 3½ tons, or rather more than that of this whiting. Say that the lime cost us 1*l.* a ton, we sold this for about 7*s.* a ton, three times that is 21*s.*, and there was the additional half a ton, so that we got a little more in point of fact for the deposit than we paid for the lime that we put in the water.

6802. Do you find a sale for it in those other localities where it is applied?—We shall do so. The Chiltern Hills works we have only just opened, and I have no doubt that we shall put up a proper apparatus there to dry the whiting. Whiting should be dry and clean, but it did not matter to the brickmakers whether it was clean or a little dirty; but from inquiries which I have made I am satisfied that properly treated it is worth certainly from 15*s.* to 16*s.* a ton.

6803. Do the waters of those five localities present any considerable difference?—There is a considerable difference in the qualities of the waters. At Castle Howard the original hardness of the water is 22·1 degrees, and it contains in solid contents per gallon 28·4 grains. The water softens down to 4·3 degrees, and the solid contents in the water are 10·75 grains. At the Caterham works the original hardness of the water is 18·74 degrees, and the solid contents per gallon 26·84 grains. The degrees of hardness when softened are 3·5, and the solid contents 9·84 grains. At the Herbert Hospital, where I should say the water is supplied by the Kent Company from their wells, the original degree of hardness is 22, and the solid contents per gallon 29·48, and when softened it softens down to 7½, and the solid contents per gallon to 15·1. At the Chiltern Hills the original hardness of the water was 13·25, and the solid contents in grains per gallon 21·6, and the water when softened was 2·2 degrees, less than 2¼, and the solid contents per gallon 8·24 grains.

6804. Then the result in different localities is different?—The result is different with different quality of waters; but when you get what I term the pure chalk water, the water got where the chalk is not covered with London clay, or interfered with by any superficial deposit, the quality of the water from the chalk is almost uniform; whether you take it at Hull, at Great Grimsby, or Bridlington, or Tring, or Watford, or Brighton, or any place where the chalk is not covered by a superficial deposit of London clay or plastic clay, you find the water almost of one uniform quality; sometimes it will contain one or two or three or four, more or less, grains of bicarbonate of lime; but that is the only difference that you find in the quality of the water.

6805. I am aware that there is no great difference in the quality of the water in different parts of the chalk; but my question was with reference to the result which you obtained after subjecting the water to your process?—After subjecting the water to the process, my experience is, that where the chalk has not been covered by London clay or by plastic clays, it almost always comes down to from 3½ to 2½ degrees of hardness. In the district south of London, if you take the North Downs, which supply the Croydon and Caterham works, and so on, it softens down to 3½ degrees; the Chiltern Hills water softens down to 2¼ degrees; the water taken at Watford, or St. Albans, or Redbourn, or Tring, softens from 22 down to 2·6 degrees.

6806. The Caterham Waterworks are on the lower chalk, are they not?—The fact is that at Caterham we go through something like 130 or 140 feet of gravel or more before we come to the chalk at all; they are on the top of a hill. We are 700 feet above the level of the sea, and we go through the chalk into the upper greensand. I for this purpose call the upper greensand anything lying above the galt clay chalk; probably geologists would call it the upper greensand. A great deal of our supply does come from the upper greensand; half of it comes from the chalk; and a large portion from a bore-hole that we have made into the upper greensand; we rather avoid going through the galt.

6807. Has the Caterham water been analysed?—Yes, frequently. I have an analysis of it here, made by Mr. Campbell, dated the 21st of July 1862, and it is as follows:—

"On the 14th of July instant I visited the Caterham Waterworks, and took specimens of the water, for the purpose of making a chemical examination of the same, from the reservoirs, just as it is supplied to the consumers, and I beg to report as follows:—

"The water was found to be at a temperature of 50° Fahrenheit. It had a fresh pleasant taste, was perfectly colourless, with a brilliant appearance. It is very well aerated, and gives no deposit whatever on standing.

"The total solid contents per imperial gallon of 70,000 grains, at 60° Fahrenheit, were found to be 8·96 grains,

Consisting of—

Mineral matter	8·64	„
Volatilized matter	0·32	„
Degrees of hardness by soap test	3·5	„

"The mineral matter was found to be of the usual composition of mineral matter in such water. The volatilized matter did not blacken on heating, indicating the absence of what is generally known as organic matter in water.

"As stated above, the hardness was 3½°, which is only about one-fourth to one-fifth of the hardness of the water now being supplied to any portion of the metropolis.

"Before concluding I may add that when taking the above specimens I spent many hours at the works examining carefully the way in which the softening process was conducted there, and I was much gratified both with the various appliances I saw and the truly substantial but yet economical way in which they were carried out."

6808. Have you also an analysis of the water from the Chiltern Hills?—Yes.

6809. Will you have the goodness to put in that analysis also?—Yes; it was made by the same gentleman, under date the 13th of March 1865, and is as follows:—

"Chiltern Hundred Waterworks Company.

"I beg leave to report to you the results of my chemical examination of a specimen of the above company's water received from you on the 28th ultimo.

"The water was contained in four Winchester quarts, and was perfectly bright and colourless.

S. C. Homersham, Esq.

12 March 1868.

"An analysis of the water gave as follows:—

Total solid contents, per gallon	-	20·16 grains.
Consisting of—		
Mineral matter	-	19·44 „
Volatilized matter	-	0·72 „
Degrees of hardness	-	13·25 „

"The mineral matter is of the following composition:—

Silica	-	1·44 grains.
Carbonate of lime	-	12·96 „
Magnesia	-	0·37 „
Chloride of sodium	-	1·17 „
Other salts of soda and potash	-	3·20 „

Nitric acid, a trace.

"There is neither iron nor sulphuric acid present in this water, the latter of which as sulphate of lime is so troublesome in boiler construction.

"When the above water is submitted to the liming process of Dr. Clark, a very beautiful, bright, and colourless water is the result, which gave as follows:—

Total solid contents, per gallon	-	8·24 grains.
Consisting of—		
Mineral matter	-	7·64 „
Volatilized matter	-	0·60 „
Degree of hardness	-	2·2 „

"I have ascertained with great care that for every 1,000 gallons of the spring water 80 gallons of saturated lime water made with the spring water are required to soften it to the degree of hardness stated above.

"The softened water was exposed to clean lead for five days at the rate of one gallon of the water to five square feet of lead, which is a very severe test, and the conclusion I have come to is that the softened water has no practical action upon lead.

"From the above results it will be seen that the softened water is exceedingly soft and free from organic impurities, and is of first-rate quality for all domestic uses as well as manufacturing purposes."

6810. Has this process been applied at Hull or Brighton?—No, it has not. I think it is very little known at Hull. I was at Hull about a fortnight ago, and then saw the well that supplies the town, and which yields from 4½ to 6 million gallons of water per day, and I found they had not applied this process there; they did not seem to have heard of it even.

6811. Has your process any effect also upon any organic matter contained in water?—I very much doubt myself whether there is any impure organic matter in the original water as it comes from the subterranean springs. I believe, if you take water from the chalk, put it in a covered reservoir immediately, and keep it covered, as far as wholesomeness goes it does not contain anything deleterious; but if water does contain any organic matter, and you apply the softening process to it to a great extent, you take down the organic matter.

6812. What has been the effect of it when tried upon river water?—I saw it tried upon a very large scale at the Chelsea Waterworks in 1850, and I have a copy of the notes taken by Mr. James Simpson, junior, at the time that the trial was made. I think something like 3,000,000 gallons in one operation were softened The effect was this, that if the water operated upon is filtered water, so that it is water itself clear before you apply the lime, the deposit settles quickly, and you have no difficulty; but if the water contains any clay, or is discoloured by a flood, as river water frequently is, the organic matter in the water, or whatever it may be which discolours the water, mixes with the crystals of the carbonate of lime and alters the specific gravity, and they do not fall down but keep floating about in the water. The result is, that you must filter that water after it is softened. There is no difficulty in filtering the water after it is softened. I have known this done at Manchester, at Hoyle's works; they softened the water by putting lime in the water on a very large scale. The water was invariably filtered after the lime was added to it, but they found no clogging up of the filter, and nothing to prevent the water being filtered after it was softened.

6813. You find more difficulty in applying the process to river than to spring water?—Yes, because the river water will not clear. The softening is just exactly the same, but to get the deposit out and get the water away clear is the difficulty.

6814. Is it attended with great expense?—Yes, with river water it would be attended with great expense; it might take 36 or 40 hours for the deposit to settle down to the bottom, so that you must filter as well as soften.

6815. That would tend to clog the filter, would it not?—No, I do not find that it tends to clog the filter. I say that is a most remarkable circumstance, that there is no clogging of the filter, or anything of that sort. The first place where I ever saw the process in operation was at Hoyle's works at Manchester. At the time I examined it they had had it in operation for some time, not so much for the purpose of softening the water as to clear it of organic matter. They are large printers, and they wanted to get the water clear again for some of the rougher processes. After they had used fine spring water, and had got it discoloured in some of their processes, they put a certain amount of lime with it, not so as to have any excess of lime, but just as much as would neutralize the bicarbonate of lime in the water, and then filtered it through a filter; they did so for several years, and they did not find the filter to be stopped up or fouled or injured in any way. I may state that for eight or nine years I have had this softened water passing through the most delicate water meters, but we have never had the slightest bit of fouling or injury to those water meters or to any pipe through which it has gone. I took out some pipes last autumn which the softened water had been passing through for something like five years, and the inside of the pipe was just as clean as the day it was put down.

6816. (*Col. Harness.*) If you applied the process to the Chelsea water would you prefer it filtered before softening or after softening?—I should prefer not to apply it at all, that is to say, I think river Thames water under any circumstances, whether you soften it or whether you do not soften it, is quite unfit for human consumption. But provided you had a choice it would require some experience to know what was best to be done. I could not say, but I think I should have it softened before it was filtered.

6817. (*Chairman.*) Would not your system of softening throw down all that was held in mechanical suspension?—No; when you deal with live organisms such as you have in the Thames water, and as you have in lake water like Loch Katrine and other lake waters, you cannot get rid of them by lime or any other process, the things will live notwithstanding.

6818. What is the proportion deposited as compared with the quantity of lime put in?—There are 3½ tons of chalk deposit for every ton of lime added to the water.

6819. (*Mr. Prestwich.*) Do you find it throw down anything besides lime and carbonate of lime?—In the waters which I have had experience of there has been nothing to throw down, the water was quite clear before we softened it, and quite clear after we softened it.

6820. In all the waters there would be a certain quantity of other salts. If there be bicarbonate of magnesia in the water, it will throw it down. As I have stated, the water supplied to the Herbert Hospital is softened, and I have here an analysis of the water by Mr. Abel, in a book published by Captain Galton, giving a description of the Herbert Hospital. It is as follows:—

"The water supplied by the Kent Company to the Herbert Hospital Waterworks contains 28·38 grains of solid matter per imperial gallon. The proportions of the principal solid constituents in a gallon of the water are as follows: carbonate of lime 15·95 grains, carbonate of magnesia 2·10 grains, sulphate of lime 6·12 grains, chloride of sodium 3·21 grains, organic matter 1·00 grains, total 28·38. The foregoing analytical results show that the

hardness of the water is very considerable; estimated by Dr. Clark's soap test it amounts to 21° of hardness; it was therefore necessary to submit it to Dr. Clark's softening process before it would be fit for hospital use. In the preliminary experiments with the water supplied to the Herbert Hospital, it was found upon examining the water directly after its treatment with lime water (*i.e.* as soon as it had become clear) that its hardness was reduced from 21° to 9°; when the softened water was left undisturbed for 12 or 24 hours the hardness was reduced to 8° and 7°. This difference is due to the circumstance that a small proportion of the carbonate of lime separates gradually from the water in a crystalline form. As the softening tanks at the Herbert Hospital works are so arranged that the softened water will remain in the depositing tanks at least 12 hours, it may be considered that the average reduction of hardness of the water supplied to the hospital will be from 21° to 8°."

6821. You have had great experience, have you not, in the supply of water from the chalk districts?—Yes.

6822. You were engaged I believe extensively in the experimental works at Watford?—No, I had nothing to do with the experimental works there. Mr. Robert Stephenson gave me the particulars of those experiments, but I saw nothing of them myself.

6823. Were those waters ever tried with this process?—Yes, frequently; and here is an analysis of that water from Watford, which softens down to 2·6.

Analysis of the evaporated Residuum of Batchworth Spring Water.

	Grains per gallon.		Degrees of hardness.	
	Original.	Softened.	Original.	Softened.
Carbonate of lime	17·60	1·65	17°·60	1°·65
Nitrate of lime	0·08	0·41	0°·05	0°·25
Nitrate of magnesia	1·42	1·65	0°·95	0°·70
Nitrate of soda	—	0·09	—	—
Sulphate of soda	0·50	0·50	—	—
Chlorides of sodium and of potassium.	1·30	1·30	—	—
Phosphates (precipitated by ammonia from acid solution).	0·28	0·28	—	—
Silica	0·82	0·57	—	—
Volatile matter, including some nitric acid.	1·00	1·15	—	—
Residue on evaporation	23·00	7·00	18°·60	2°·60
Subtract latent hardness (magnesium salts)			0°·95	0°·00
Sensible hardness			17°·65	2°·60

6824. (*Chairman.*) That is exclusively a chalk water?—Yes, that is exclusively a chalk water. There is one great advantage in softened water, and it is a great advantage, that if you put a quantity of this softened water into a reservoir open and exposed to the air, it will remain as clear and good at the end of six months as it was the day you put it in; but if you fill a reservoir with perfectly clear spring water from the chalk, and put it into a reservoir as clean as a china basin, the water, in the course of two or three days in the summer time, will become covered with masses of confervæ, then insects follow, and the water becomes putrid—not because the water itself has anything in it to cause this putridity, but because it contains bicarbonate of lime, and the spores of the confervæ brought in the air live upon this bicarbonate of lime, and form upon the top of the water large floating masses of living organisms, which soon begin to decay, and then insects appear upon them; in a very short time the whole of the floating masses on that water becomes putrid. I acted for a great many years for the Brighton Water Company, and we pumped the water into a reservoir under the race-course. You might say the reservoir was as clean as a china basin. There was no puddle in the reservoir, it was perfectly tight, and rendered inside with cement and lime whitened. The surface of the water in summer put into this reservoir within two or three days was one mass of growth of confervæ and insect matter, and other sorts of impure matter. Now, when you soften that water before you put it into the reservoir, it may remain there for six months, and is as good at the end of six months, excepting that it may catch dust and impurities from the air, but it does not putrefy, nor do any organisms form in the water or on the water.

6825. Applying your principle of action at Plumstead to the cost of the application of the system if applied to the metropolis, assuming only 100,000,000 gallons per diem, I find that it will cost, in round figures, 80,000*l.* a year?—That is, I suppose, provided you have nothing in return for your deposit. The actual cost is 600,000*l.* for structural works, and if you take that at four per cent., it would be more like 24,000*l.* If you take 600,000*l.* at 10 per cent., it would be 60,000*l.*, and at five per cent. it would be 30,000*l.* In your calculation you do not take anything into account for the value of the deposited chalk or whiting. The whiting, as I said, at Plumstead paid for the lime. Without drying it, or giving ourselves any further trouble than letting it go into a sort of receptacle to get somewhat hard, we sold it, and it was carted away for brickmaking at 7*s.* per ton. If it was properly dried I am satisfied it would pay the whole expense, including the interest of the capital for constructing the reservoirs.

6826. (*Mr. Prestwich.*) Have you tried any experiments as to the quantity of air in the water before the process and after the process?—I have. I do not find that the air is injured in the slightest degree. The quantity of gas in the water after it is softened is precisely the same as before it is softened. I hold in my hand an analysis dated May the 4th, last year, on this point, made by Mr. Campbell, at my particular request, with respect to the Caterham water. The water was supplied to Mr. Campbell on the 29th of April, and he immediately analysed it for the gaseous contents, and the contents of softened water, drawn from a consumer's tap, were as follows:—There were 7½ cubic inches of air in the gallon, and that consisted of 2½ cubic inches of oxygen gas and 5 cubic inches of nitrogen gas; in addition, the little chalk that was in the water gave ·75 cubic inches of carbonic acid per gallon, but the carbonic acid was in combination with the carbonate of lime. Chalk, to the extent of about three-quarters of a grain per gallon, is soluble in the water, so that after your softening you have three-quarters of a grain of chalk in the water. If you take water from Loch Katrine, and analyse the air in the water at the loch, and analyse the air in the water in Glasgow, you will find this remarkable difference, that the loss of oxygen gas in the water going from the loch into Glasgow is 10 per cent. In the proceedings of the British Association for 1861, page 94, Dr. Wallace, a Fellow of the Chemical Society of Glasgow, states his analysis of the gaseous contents of the water taken direct from the loch and of the water taken from the mains at Glasgow to be as follows:—At Loch Katrine it contained 7·5 cubic inches of air or gas per gallon. At Glasgow it contained 8·5 cubic inches of air or gas per gallon. But when you examine the quality of the air in the Loch Katrine water taken direct, and that taken from the pipes at Glasgow, there is this difference, the carbonic acid in 100 parts was 1 in Loch Katrine, and 4·5 in Glasgow; the oxygen gas was 33·4 in Loch Katrine, but it was only 29·9 in Glasgow; and the nitrogen gas was the same in both cases, 65·6, making 100. Persons acquainted with Loch Katrine, and with the quality of lake water in general, would easily account for that. Lake waters are full, so to speak, of organisms and decomposing organic matter, and the oxygen gas is destroyed by the decomposing matter, or it destroys a portion of the decomposing matter and forms carbonic acid gas, so that you find 4½ in the 100 of carbonic acid gas in the Glasgow water taken from the main at Glasgow, and you only find one at Loch Katrine; but you find the oxygen gas diminished in Glasgow to 29·9, although in the loch the water contained 33·4.

S. C. Homersham, Esq.

12 March 1868.

I have had very large experience for many years of water impounded in large reservoirs, and I have taken water from the reservoir that I was connected with at Todds Brook at the head of the Peak Forest canal. It there contained only two or three grains of mineral matter per gallon; but in the autumn, if you take a glass of water out of the reservoir, and look at it with your eye, you can count 20 different insects in it. My business frequently takes me to Manchester, and I have taken a decanter of the water at Manchester and looked at it, and I could see the living organism in that water by just holding the decanter against the light and looking at it; and if you take a globular glass vessel, such as the globes in which gold and silver fish are kept, and which assists in magnifying those insects, you can see them jumping about in all directions. In spring water from the chalk you never find organisms, or an insect of any kind. Those organisms live upon decomposing organic matter.

6827. The quantity of air in the two waters I see is much about the same, the Caterham water you say contains $7\frac{1}{2}$ cubic inches per gallon?—Yes, but the proportion of oxygen is larger in the Caterham water taken direct from the pipes.

6828. What is the quantity of oxygen in the unsoftened spring water?—I have not an analysis *pari passu* with the softened water now, but I have had it tried frequently, and it is exactly the same in the spring water as in the softened water; but you must always take this with my answer, that if you take water from a spring in the summer time and put it in a tumbler, the normal temperature being of 49° or 50°, and merely let it get warm by letting it stand in the sun till it is up to 60° or 70°, you have lost some of that gas out of the water from the mere increase of temperature. The water will not hold at a warm temperature so much oxygen gas in solution. The reason why the Thames smelt so bad some time ago was because in the summer time the temperature of the Thames varies from 68° to 72° or 73°, and there is a necessary loss of oxygen gas from the mere increase of temperature, and the organic matter decomposes more freely in hot weather than in cold weather. The decomposing organic matter also tends to deoxydise the water in the Thames, and this impure matter in solution in time comes to smell, as it did some two or three years ago.

6829. What is the reason for your expressing a preference to covered reservoirs?—Taking my experience at Plumstead those reservoirs were as well constructed as any reservoirs could possibly be for uncovered reservoirs; there was a wall surrounding them 77 feet high close in, and I found this, that in certain hot weather, when there was hardly any wind blowing, I would go round the reservoirs and see a heap of black something lying on the top of the water. I made the observation, the man has not been paying attention to his chimney, it is soot; but he said, no, there was nothing from the chimney, and on looking into the matter closely I saw that it was a whole mass of insects which had been sent against the wall of the reservoir and bounded back into the water; whole heaps of insects would fall into the water; also you cannot keep leaves out; in the autumn leaves will get into an uncovered reservoir, and impurities of a kind which you will hardly believe; large flies, tadpoles, and all kinds of things will get into the water if the reservoirs are uncovered, and all the softening reservoirs that I make now I invariably cover.

6830. (*Mr. Harrison.*) I gather from your evidence that your object would be to supply London entirely with spring water from the chalk, and to do away with the present supply taken from the Thames?—Yes, but when I say that I would do that, it would do itself if the Government would allow it to do itself. The only improvement that has been made in the London water supply has been made in the south of London, after the Plumstead works were made. The Plumstead works were made under considerable difficulties; we did not dare apply for an Act of Parliament because we felt sure that we should not get it if we did apply for it. The consequence was that the works were made by the inhabitants of Plumstead without an Act. The Kent Company at that time were supplying water from the river Ravensbourne, which is not only a very hard water, but is very impure in other respects. The new works were made, and as soon as we got into operation and got about 1,000 consumers attached to our mains, the Kent Company, knowing very well how many we had attached to them, inasmuch as most of our consumers were detached from their mains before they were attached to ours, sunk two wells, and they worked first one well and then another, not for the purpose of getting spring water for themselves, but for the avowed purpose of draining our wells, as their engineer said that would be the easiest way of getting rid of our competition; they put down very powerful engines, first one and then another, and worked them night and day for many weeks and months together, under the firm expectation that they were going to drain our wells, but still they did not affect them.

6831. My question was, whether your view was to take the water from those springs in substitution of the present supply from the river Thames?—In substitution of the present supply from the river Thames, certainly; but you must take this into consideration, that the New River Company now get their additional supply themselves from wells in the chalk. The Kent Company also now supply all their water from the chalk, although not taking it from the best source in the chalk.

6832. Have you considered at all the means of getting not only a supply equal to the wants of the present population, but to those of a largely increasing population?—Yes; I consider that to the tune of 10,000,000,000 gallons a day there would not be the slightest difficulty in getting it for the supply of Logdon.

6833. Have you made any estimate of the cost?—The cost is something inconsiderably small, you would be surprised to know at what a small cost you can get this chalk water. I will give a practical illustration. When we set out to make the Plumstead works, we set the works up to supply 600,000 gallons a day, and when we had driven our tunnels under ground and got 600,000 gallons, we did not trouble ourselves to get any more water, and the total cost was something like 2,500*l.* In the course of four or five years our consumption came very nearly up to 600,000 gallons a day, and it was requisite to do something. I said we must either drive some tunnels or put a bore-hole. I recommended a bore-hole, and we did so; we put down a bore-hole 18 inches in diameter, and about 500 feet deep. The total cost of that to the company was about 700*l.* to 800*l.* We contracted with Messrs. Mather and Platt to put in the bore-hole for 500*l.*, and we found the steam for working the steam-boring machinery, and some other expenses which might have brought it up to 700*l.* or 800*l.*, not more. We got by that bore about 600,000 gallons per day more, and that was the additional cost of getting another 600,000 gallons. Brighton has increased its water in this ratio; it is a very large ratio; Brighton is a very increasing place. I was connected with the company from 1846 to 1853 or 1854, when another company got an Act of Parliament, and we sold our works to them, and then my connexion with that company ceased; but in 1846 the company which I represented had 2,700 tenants; in March 1853 we had 7,260. In 1846 we supplied 800,000 gallons a day; in 1852 we supplied 2,500,000 gallons a day; and I should say that something like 3,000*l.* was the cost of increasing that supply from 800,000 gallons to 2,500,000 gallons. The readiness and cheapness with which water can be got from the chalk in well-selected situations would hardly be believed except you went very closely into the subject, and knew how readily it could be done. I have drawings of wells actually constructed that are in actual operation. Here is a drawing of the first one sunk at Croydon (*producing a drawing*). Croydon has been supplied from the chalk for a great many years, and that well supplies 2,000 gallons per minute.

S. C. Homersham, Esq.

12 March 1868.

There is a bore-hole 77 feet deep from the surface. For 20 feet from the surface there is a well 9 feet in diameter; for 10 feet deeper there is a well 6 feet 6 inches in diameter; then there is a bore-hole 24 inches in diameter for 24 feet deep; and then there is a bore-hole below that 12 inches in diameter for 23 feet, making the total depth from the surface 77 feet. The whole amount that the water is depressed, when the well supplies 2,000 gallons of water per minute, is 13 feet 9 inches.

6834. Do you mean depressed by the pumping?—While we are pumping at the rate of 2,000, gallons per minute the level of the water is lowered, the whole water line in the well is depressed 13 feet, but when we are not pumping, the water rises to the original level.

6835. You are constantly taxing the water in the chalk, and therefore you keep down that depression?—No, we do not tax the water in the chalk, because we take much less out of the chalk than comes into it. If you pour 50 gallons a minute into a basin and only take 20 per minute out, you will always have more water than you take.

6836. By reason of your pumping you have depressed the general water line 13 feet, have you not?—No, that is not so; when we are not pumping the water stands at the same level as it did at first. While we are pumping this particular well at the rate of 2,000 gallons per minute the water level is lowered 13 feet 9 inches; but when it is once lowered 13 feet 9 inches it gives 2,000 gallons per minute, and you may pump it night and day and it does not lower any more. And if you leave off pumping for a short time it rises again to its original level, and you have not made any permanent depression. I was at Hull the other day, where the depression when pumping is something like 35 or 36 feet; from that well they get from 4,500,000 to 6,000,000 gallons per day, that is to say, in summer they require nearly 6,000,000 gallons, but in winter they do not require more than 4,500,000, therefore they take out of the well only what they require, and they only depress the water level when pumping some 35 feet.

6337. (*Col. Harness.*) What is the level of the surface of the well with regard to high-water mark?—It is from 80 to 90 feet above high-water mark at Croydon. I am now pumping from a well in the Chiltern Hills, where the water stands at 470 feet above high-water mark.

The witness withdrew.

Adjourned to Wednesday next at 12 o'clock.

Wednesday, 18th March 1868.

PRESENT:

SIR JOHN THWAITES IN THE CHAIR.

Alderman Sir BENJAMIN PHILLIPS.	THOMAS ELLIOT HARRISON, Esq.
Colonel HARNESS.	JOSEPH PRESTWICH, Esq.

THOMAS CROWTHER BROWN, Esq., examined.

T. C. Brown, Esq.

18 March 1868.

6838. (*Chairman.*) Are you a native of Cirencester?—Yes, I have lived in the district all my life. I have no personal interest at all in this question, but I have for many years as an amateur studied the chemical and geological features of the present case, and for 23 years have kept a daily register of the rainfall at Further Barton, one mile from Cirencester. I have brought with me a little map of the district to which my evidence particularly refers, and you will see by referring to it that it embraces the valleys of the Churn and the upper part of the Thames, and I have drawn on the map lines which are supposed to be the watershed, because on the one side we have the Colne, and therefore I assume that one-half of the area of the watershed belongs to the river Colne, and I assume that the other half belongs to the river Churn, there being a ridge of hills which separates the two sheds, and on the other side of the hills it is the same. There is the Stroud river which drains to the west, and I have served that in the same way. I only point that out to show that my calculation is upon the area inclosed by the two watersheds.

6838*a*. Have you the result of the gaugings to which you have referred?—Yes, and I will hand it in. The first is a monthly register of the rainfall at Cirencester from the year 1845 to 1868, and I have also given the yearly average of 30 inches, and it contains the monthly averages under the separate years, and the variations in the rainfall.

MONTHLY REGISTER of the RAINFALL at CIRENCESTER from the year 1845 to 1868.

	1845.	1846.	1847.	1848.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	1857.
January - -	1·90	4·65	2·77	1·22	1·92	2·01	4·05	5·70	4·10	2·98	0·43	3·35	3·03
February - -	1·00	1·40	2·40	4·05	1·75	2·03	0·85	1·70	1·05	0·96	1·25	2·10	1·55
March - -	1·30	1·87	1·80	3·20	0·90	0·91	4·60	0·50	1·00	0·63	2·64	1·58	1·95
April - -	1·90	3·65	1·58	3·50	3·10	4·33	1·13	0·70	2·56	0·25	0·60	3·33	2·60
May - -	2·50	2·21	2·30	0·45	3·35	3·50	1·45	2·00	3·40	2·90	2·08	3·95	1·76
June - -	3·60	1·10	2·90	4·90	1·72	1·09	2·63	6·82	3·80	1·73	2·58	1·27	2·92
July - -	2·80	2·15	1·43	3·08	1·20	5·31	1·74	3·15	3·96	3·16	4·85	1·30	2·47
August - -	2·97	4·45	0·92	2·90	0·93	1·80	2·90	5·67	3·72	0·90	2·05	4·20	1·30
September - -	3·15	1·45	2·60	4·42	3·80	2·70	0·50	5·48	1·87	0·70	2·27	3·95	1·80
October - -	1·50	6·25	5·83	5·05	2·44	1·47	2·67	3·88	4·23	2·72	5·60	3·35	3·75
November - -	3·00	1·70	2·54	1·64	1·70	3·17	0·64	8·95	2·20	1·52	0·45	1·10	1·25
December - -	3·30	1·00	3·85	3·63	3·10	2·85	1·65	4·30	1·00	1·48	1·30	2·92	0·84
Total - -	28·9	32·0	30·9	38·0	25·9	31·2	24·8	48·8	32·9	19·9	26·1	32·4	25·2

T. C. Brown, Esq.

18 March 1868.

MONTHLY REGISTER of the RAINFALL at CIRENCESTER from the year 1845 to 1868—(*continued*).

	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	Monthly Average of 24 years.
January - -	0·60	1·50	4·52	1·45	2·70	3·30	1·82	4·21	4·13	5·00	4.68	2·68
February - -	1·00	2·11	1·20	2·95	0·35	0·72	1·93	2·50	4·04	2·00	2·03	1·68
March - -	0·90	2·42	2·27	2·90	4·70	1·25	3·08	1·40	1·40	3·49	—	1·70
April - -	5·25	2·70	1·00	0·65	2·22	1·23	1·40	1·25	2·15	3·33	—	2·48
May - - -	2·65	1·25	3·85	1·15	3·95	1·40	1·50	1·92	0·73	2·98	—	2·38
June - - -	3·18	2·78	5·92	2·65	2·97	5·32	1·35	2 05	4·15	1·88	—	2·87
July - - -	2·00	1·65	1·75	3·94	2·08	0·50	0·88	5·50	2·10	4·29	—	2·68
August - -	1·97	2·48	5·05	0·90	2·25	3·65	1·24	4·00	4·54	2·57	—	2·61
September - -	2·94	3·40	3·35	3·16	3·87	3·00	3·68	0·08	7·10	1·60	—	2·73
October - -	1·76	2·95	2·00	1·74	4·72	3·75	2·25	6·46	2·15	3·50	—	3·56
November - -	0·83	2·77	3·00	4·10	0·55	2·10	3·30	3·67	2·03	1·05	—	2·23
December - -	2·56	2·95	3·05	1·80	2·10	1·73	2·25	2·78	3·45	2·01	—	2·45
Total - -	25·6	28·9	36·96	27·39	32·46	27·95	24·6	35·82	37·97	33·70	—	30·0

6839. Are those results from one gauge, and at the same point?—Yes, from one gauge, and at the same point. I have also prepared a paper showing the total amount of rainfall in that area, and that is a calculation which I believe you will find to be correct:

CALCULATION of the annual and daily RAINFALL in the district witness treats of, and the whole area drained by the rivers Thames, Swill Brook, Churn, Coln, Lech, Windrush, and Cole.

Average fall of rain 30 inches.

Square feet in 1 acre - - - - - -	43,560	being cubic feet of water 1 foot deep.
	43,560	add 1 do.
	21,780	6 inches.
	108,900	cubic feet of water per acre per annum.
	6	gallons per cubic foot.
	654,400	gallons per acre.
	640	
	418,176,000	gallons per square mile.
	90	square miles.
	365)37,635,840,000	total gallons rainfall on 90 square miles.
Average daily rainfall on 90 square miles - -	103,115,700	
	4	this area being about ¼ of Cotswold Hills.
Total daily rainfall of district drained by Thames, Churn, Coln, Lech, and Windrush.	412,462,800	

I begin by taking the superficial feet contained in an acre, and then calculating it at one foot in depth. I have given the cubic feet for one foot, and I have added another cubic foot for two feet and a half of that quantity again to make up 30 inches of rainfall for the year. The number of cubic feet multiplied by six gives the number of gallons per acre, and that amount multiplied by 640 acres gives the number of gallons per square mile. The number of square miles I calculate to be 90, and that multiplied by 90 gives the total rainfall of the district which I refer to, and that you will find amounting to 418,176,000 gallons. Having given the total rainfall, which is an enormous quantity, as you observe, I wish to explain the way in which it is disposed of and what becomes of it. It is disposed of, first, by rivers, as in this case the Churn and the Thames are the surface drains; secondly, by evaporation. That evaporation is confined to the surface, for excepting in very warm weather, when the heat assists the evaporation, it is merely surface evaporation, and that varies, as we very well know, very much in summer and winter. But in addition to evaporation is the action of living vegetables taking up water by their roots during the period of their growth, which appears to me to be an enormous quantity, but which it is impossible to ascertain. We know perfectly well that vegetables depend upon water, and take up water, and disperse an enormous quantity in the atmosphere; it is disposed of, thirdly, by irrigation. In those pretty considerably descending valleys of the Cotswolds it is a very general practice to water the grass meadows, and those meadows are flooded for a time, and of course a great deal of water is lost in that way, because there is evaporation going on there, besides the stimulus to the plants, and in addition to that a portion of that water descends by gravitation into the soil; fourthly, it is disposed of by gravitation into the lower strata, that is another element which we cannot ascertain, but which I believe is very great indeed, for I believe all of what we call the impermeable beds, the clays are only so to a certain extent, and that they stop water in quantities; but there are also besides that large quantities passing through into the lower strata. For instance, in the Cotswold Hills, on the upper oolite where the rain falls, it descends till it comes to the fuller's earth, and when it comes to the fuller's earth a great deal is thrown off, no doubt, with the clay, but other portions pass through that fuller's earth into the lower oolite, and there we know there is no difficulty, it will go into the sands of the lower oolite, and perhaps only find a stop in the lias beds. Another great loss is by floods. When we have great rains in winter there is a great deal of surface water thrown out and that passes rapidly down the valleys and flood) the Thames and all the valleys connected with it, and is carried off and cannot be arrested; there are no facilities for making reservoirs to arrest it; and besides that the flood water is very impure, the flood water may be considered as a scavenger, for it carries everything that it finds on the surface of the earth in its flood. I next wish to explain the strata and soil of the district.

6840. Let me ask you whether you have taken any means, or have observed any other person who has taken means, to ascertain the net result of the area which you have now described, that is to say, after

allowing for evaporation and absorption, what the net result is which finds its way into the surface rivers; has that been gauged by yourself or any other person to enable you to judge as to the quantity due from that district?—Yes, I have had an opportunity of reading the evidence of Mr. Taunton on that subject before the Rivers Commission, and as far as that goes his gauge of the river shows how very little of the rainfall is carried into the rivers, and also how untrustworthy the gauging is. Now Mr. Taunton states that he gauged the Thames at Buscot in 1864, and he found only 1,166,000 gallons passing the Thames at Buscot, and he also gauged in 1854 the Coln at Fairford, and that he made to pass daily 1,692,000 gallons. I think nothing can more clearly show how untrustworthy the gauging of rivers is than that, for this larger amount is only from one river, the Coln, whereas the other, of the Thames at Buscot, includes the Thames proper, the Churn, the Leach, the Coln, and the Cole; so that I cannot answer the question of my own knowledge; but from what I find from others I think it is very difficult, indeed I may say almost impossible, to ascertain what portion of the rainfall does get into the rivers, there are so many circumstances to hinder the proper gauging of rivers. I will now proceed to explain the nature of the strata and soil of the district, because that has a very important bearing upon what I shall have to say hereafter; and, first, as to the chemical nature of the soil, I will not say that I can give you exactly what a chemist does, but it is very nearly correct. The soil of the district contained in the map which I have handed in is composed of about 45 parts of lime, 45 parts of clay, and 10 parts of silex, that is the surface soil. This soil readily absorbs the greatest rains, and the water descends by gravitation until it is arrested by an impervious stratum. The great stratum of the fuller's earth placed between the upper and lower oolites is the main stopper to the descending water. But not only is this bed merely a partial stopper, for it has so many faults in it that vast quantities of water pass at those faults into the lower oolites, and ultimately into the sandbeds resting on the lias, and from thence probably into the sea. I have here a little section (*producing the same*) which I had for a great many years when I was a director of the Cheltenham Great Western Railway; it is a section made by the resident engineer of the present tunnel of the Great Western Railway, showing the fault. Now it is obvious that water descending through this stratum has a vent somewhere, and therefore we may say that but a very small portion indeed of the rainfall is turned out by the fuller's earth beds; and I know of other faults myself. Besides the fuller's earth the upper beds of the upper oolites have numberless local beds of clay, as the Forest marble and the Bradford clay, none of which are absolutely impermeable, but being near the surface they throw out water during great rains and supply the winter wells. Thus it is impossible to look to the total amount of rainfall as a source of supply, the rivers take but the smaller part of it, the rivers only exist in valleys having springs. Some of the Cotswold valleys are dry. The Churn owes its very existence to this coating of fuller's earth, which holds the water in its descent from its first source, and the springs from the fuller's earth cause that river. The next valley is a dry valley which runs down to the Thames, there is no water in it, and there never is any water in it, it never cuts a spring. I now propose to come to the subject of the dip of the wells, and will hand in the following table, which shows the winter and summer supply of the wells at Cirencester.

Rise and Fall of Water at Cirencester in the Gravel Bed.

Month.	No. 1.						No. 2.				Dip of Water in a Hill Well 100 ft. deep.		
	1863.	1864.	1865.	1866.	1867.	1868.	1865.	1866.	1867.	1868.	1866.	1867.	1868.
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
January	7 3	7 7	9 8	6 7	6 11	9 9	—	11 5	11 9	14 7	26 8	25 8	21 0
February	6 5	7 3	6 10	5 10	6 0	6 10	—	10 7	10 11	11 9	31 0	30 0	38 8
March	7 6	7 1	5 7	6 2	6 6	7 7	11 3	10 11	11 8	12 5	27 4	25 9	21 5
April	8 3	6 6	6 11	7 8	6 0	—	12 3	11 3	11 0	—	19 2	41 0	—
May	9 4	8 1	8 2	8 0	6 10	—	12 2	12 4	12 0	—	18 4	27 6	—
June	10 1	8 11	9 0	8 8	7 10	—	13 7	12 7	12 5	—	14 8	19 9	—
July	9 5	9 11	9 8	8 10	8 1	—	13 10	13 2	12 11	—	11 2	15 11	—
August	10 8	10 10	9 0	9 7	8 9	—	13 4	13 4	13 2	—	9 4	13 6	—
September	10 3	11 8	9 4	10 0	9 6	—	13 9	13 9	14 0	—	8 0	10 10	—
October	10 4	12 3	9 10	7 1	10 2	—	14 4	14 4	15 0	—	14 0	7 7	—
November	10 0	13 1	9 6	7 1	10 10	—	13 8	11 6	15 8	—	27 10	8 3	—
December	8 2	13 9	7 0	7 0	11 3	—	11 10	11 10	16 3	—	23 10	10 0	—
Rainfall	in. 27·95	in. 24·6	in. 35·82	in. 37·97	in. 33·70	—							

6841. Will you be good enough to explain the sense in which you use the term "dip" as applied to a well?—The dip of the deep well of 100 feet deep is an absolute dip—the depth of the water in the well. The dips of the other two wells which are in the gravel bed under the Churn are really dry dips, that is to say, the dip is taken from the surface to the water. That equally shows the rise and fall, but we have no means of knowing the depth of the water in that gravel bed. Two of those wells as I said are sunk in the gravel bed at Cirencester about 20 feet deep, and those underlie the river Churn. This bed of water has never been fathomed. The rule is to sink as deep in the gravel beds as possible, and in the driest seasons such wells never fail. It is an unseen underground river passing into the Thames by gravitation, that is evident, as it rises about 600 feet above the sea and descends 300 feet, so that there is a constant passage of water in that gravel bed. There is no doubt that the gravel bed rests upon clay beds, the fuller's earth, or the Forest marble clays, which latter appear as they approach the valley of the Thames. This gravel bed is supposed not to exist in the upper Cotswolds, where the beds of the fuller's earth throw out the springs, mainly supplying the Churn. I may here point out a singular circumstance, but which bears on the question of the loss of the water of the rainfall. The great loss of the river water occurring near North Cerney, four miles from Cirencester, probably arises from the commencement of the gravel bed, and it there leaves the river, and the water is carried in what I call an underground river to the Churn near South Cerney, where a beautiful spring flows constantly, called the Boxwell spring, which is clearly an outlet of that underground river in the Churn valley gravel, and calculated to thrown out more than 1,000,000 gallons per diem. At this point the Oxford clay appears, and is the probable stopper, causing the outburst of this Boxwell spring. The chemical composition of the oolitic beds referred to is

T. C. Brown, Esq.

18 March 1868.

the cause of the purity of the water in the wells, for not only are there no mineral substances to make it a mineral water, but the discovery of Mr. Way the chemist has proved scientifically what the facts exhibit, namely, the power of such a soil, especially in the clay, to arrest all feculant matter, and allow the rainwater which is impure passing through this natural filter, to descend into the lower strata in a pure state. It is the nature of the surface soil in the district in question that gives it such advantages over sandy soils, or silicious gravel beds, such as you have about London, and it is this feculant matter that provides nourishment to the roots of vegetables in the surface soil, and is indeed their manure. There is no doubt that all carboniferous and nitrogenous matters are thus beneficially disposed of, and preserve to us the green earth through a long time, and thus prevent that malaria which would inevitably arise where there are decomposing vegetable and animal matters, and which during decomposition is thrown into the atmosphere. The want of carrying out in towns the immediate removal of those decaying matters, but allowing them to decompose in sinks, and drains, and foul courts, is the real cause of fevers, and prevents the influence of the otherwise constant restorative powers of pure air and pure water on the human system. As a proof of the purity of the water, the following analysis of the water from wells by Mr. Church, the chemist to the Royal Agricultural College, Cirencester, will afford a proof of the correctness of the foregoing reasoning. This water was the Churn water from a gravel bed 10 feet under the surface-made soil of Cirencester, the wells being sunk 10 feet in the gravel.

Mr. Church says with regard to the Boxwell springs that the water is excellent in colour and taste, containing scarcely a trace of organic matter and no nitrous acid; that it is the best water he had examined from Cirencester, being perfect for drinking and cooking; and the analysis of two wells at Cirencester show that the water was completely free from all organic impurities. Those were Churn valley waters, but the strata of the Thames proper which we are considering, and through which the rainwater passes, is chemically the same, and no doubt a like purity would be found in its well water, that I think is unavoidable. It now appears desirable to refer to the operations of the Thames and the Severn Canal Company, as bearing upon the question. That company has 9 miles of summit level of canal, about 350 feet above the sea, falling westward to the Severn and eastward to the Thames. In order to keep up the requisite depth of water in the canal it employs two means, first, an engine at the Thames head raising every 24 hours 3,000,000 gallons of pure water 63 feet high from the fuller's earth; and, secondly, a feeder from the Churn at Cirencester, the quantity of which I have not ascertained. There are other small sources, as, for instance, where in cutting the canal they met with land springs; but those are inconstant in their flow. I have now stated to the Commission most of the facts, and although, properly speaking, it is my business only to give to you such facts as I am possessed of, yet I deem it the most important part of my duty to communicate the conclusions which I have come to, founded on those facts, especially as they form the very basis of the practical result which I imagine to be attainable. First, I need hardly point out that the rainfall of the district, if available, would be far more than sufficient to supply all the wants of London with water, to the amount of 100,000,000 gallons per day; secondly, notwithstanding that I am compelled to conclude that from the losses by winter floods, by gravitation into the lower strata, by evaporation in summer, by the quantity taken up by plants, by the quantity removed by the river, by the quantity passing into the gravel beds, and by the irrigation of water meadows, from those combined sources water in sufficient quantity to supply all the wants of London cannot be obtained from this watershed of the Cotswold, and if obtained it would not be pure water; for it is obvious that these difficulties interfere, namely, the use of water in the mills, in irrigation, and in supplying water to the whole district, it would dry up the wells, and it would be impossible to compensate all the claimants; my conclusion is that the question in this shape may be instantly dismissed. I now come to explain a plan which does appear to me to be feasible. The water supply of London is now provided by several water companies. To dismiss them altogether and draw one ample supply, as it has been talked of, say from Plinlimmon or Bala Lake, appears to me impossible, not only in the cost of compensation, but in the enormous first cost of bringing water 200 miles, and in the repairs, not to say the deterioration of the water by passing through such a length of pipes, but also from the injury arising from open reservoirs; altogether those, to my mind, are fatal objections to such a scheme. But my plan is exceedingly simple, and although I contemplate its application only to the Thames watershed of this district, yet it may be equally or even more applicable to other districts nearer London, possibly the chalk district. For instance, there is the Hungerford river, which is but little used, I believe, either for irrigation or mills; but this I leave of course to the Commission to consider, if they entertain my idea. If they entertain my idea, Mr. Prestwich, one of the members of the Commission, more than any man, perhaps, is competent to settle the source from which water should be procured. I am not a great geologist, I am only a local one, and my plan is this, to supply London with pure water for drinking purposes only. The evidence which I have before given may be now applied to show that pure water can only be obtained from wells, but that any soils composed of lime and alumina are perfect filterers, that there would be no difficulty in procuring from 6,000,000 to 9,000,000 gallons daily from the upper Thames district by pumping, and then conveying it to London; that the distribution would be readily, I believe, undertaken by the present water companies, probably by means of second tubes; that the general supply of other water to London would be continued by those companies as at present; that the measures now in operation to prevent the contamination of the Thames and its tributaries will ensure a supply of purer water than that which is at present supplied; that there are no difficulties which may not be easily overcome in carrying out this scheme at a moderate cost, from the fact that the Thames and Severn Canal Company are at this moment pumping 3,000,000 gallons of water daily from their well, and notwithstanding that the Thames is at this moment, as I saw yesterday only one mile distant from that engine, full of water. No doubt that arises from the first sources of the Thames being superficial clay beds throwing out the water, whereas the water pumped up by the Thames and Severn Canal Company is from the fuller's earth, which is much deeper down. That shows what could be done by that company in the district of its summit level, a level of 350 feet above the Thames at London Bridge, and any proposition to that company to find water it is not unreasonable to suppose would be entertained, when we know that that company, from its declining traffic, incident to the introduction of the railways, made proposals to Parliament in 1866 to convert its summit level into a railway It should also be borne in mind that in the Great Western Railway there now exists a viaduct from this very canal to Paddington, descending by most gradual gradients, and that it might be feasible on this viaduct to lay down pipes to London by arrangement with the Great Western Railway Company. The water would flow to London by gravitation, and were it not for friction it would rise to a level in a fountain in London 350 feet high I have only now just to give a summary or recapitulation of my plan, and perhaps the Commission will excuse me in detaining them so long. It is, first, to improve the quality of the Thames water by sanitary means; secondly, to continue the general supply of London by the present water companies; thirdly, to supplement this supply by pure water obtained from wells; fourthly, that the Thames upper

T. C. Brown, Esq.

18 March 1868.

sources are adequate to furnish from 6,000,000 to 9,000,000 gallons daily without disturbing the existing state of things; fifthly, it is possible that other sources nearer London may be found; sixthly, it should be remembered that pure water is not liable to decomposition like rain or river water. I hope the Commission will excuse my perhaps travelling a little out of the record, but I could not put all my ideas on the subject which I was asked to give evidence upon without going so far as this; and I have no doubt that when the Commission come to study the evidence which I have given, they will then be able to judge of what it is worth. I shall now be most happy, in addition to what I have already stated, to answer any questions which it may please any member of the Commission to ask me. What I have given is my simple report.

6842. (*Mr. Prestwich.*) What is the level of your rain-gauge above the sea?—It is about 400 feet. I am about 60 or 70 feet above the town of Cirencester, the town is therefore 340 feet above the sea.

6843. Do you know any other gaugings of the Thames and the Coln besides those of Mr. Taunton?—No.

6844. Have you gauged any of the springs in your district?—I tried to gauge the Boxwell spring, which is very near the union of the Churn with the Thames, but I did not succeed. I have therefore assumed Mr. Taunton's estimate of 1,000,000 gallons a day, and I believe that is correct; but there are a great many other springs in the Thames valley between the pump of the Thames and Severn Canal Company and the Thames at Cricklade.

6845. Do you know the level of those springs above the sea?—Very nearly; there is a gradual fall from the summit level, which is I think 350 feet, of about 80 feet to Cricklade.

6846. That would give the limits of the principal springs I suppose?—Yes.

6847. Are those springs permanent, and uniform in their delivery?—The Boxwell spring is permanent, the spring that filled the Thames yesterday is not permanent, it has a very superficial bed of clay that throws off the water, and it is generally dry in summer.

6848. Have you had the water in the various springs analysed?—Yes, I have handed in the Boxwell spring analysis by Mr. Church.

6849. You stated his opinion, but have you got the exact chemical analysis with you?—I could not lay my hand on Mr. Church's paper, but I copied it into my pocket book, and I have given you the substance of it.

6850. We should like if possible to have the exact analysis?—That I cannot give you.

The witness withdrew.

Captain Edward Burstal further examined.

Capt. E. Burstal.

6851. (*Chairman.*) You are the secretary to the Thames Conservancy Board, I believe?—I am.

6852. As appears from the evidence of Mr. Thorp, the deputy chairman of the Conservancy Commission, you have served notices, have you not, upon all the towns upon the banks of the river Thames, to the extent of your jurisdiction?—Yes.

6853. And I believe on the receipt of those notices certain difficulties arose as to what was the intention of the Thames Conservancy Board with regard to the degree of purity that they intend to insist upon, or that the Act could authorize them to insist upon?—I may state that the board were desirous of being able to form a correct opinion as to what should and as to what should not be allowed to come into the Thames, and with that object in view they considered it desirable that they should apply to three eminent chemists, Dr. Frankland, Dr. Letheby, and Dr. Odling, for the purpose of getting a report from those three gentlemen as to the standard of purity of the sewage water when defæcated, for being admissible into the Thames. Those gentlemen instituted a great number of inquiries, and the result has been a report which I will now hand in.

The same was handed in, and is as follows:—

Thames Conservancy,
41, Trinity Square, Tower Hill,
August 6, 1867.

Sir,

I am directed by the Conservators of the River Thames to request that you will report to them, conjointly with Drs. Frankland and Odling, whether fluid which has been mixed with sewage can be so purified as to be admissible into the river Thames; if so, in what manner it may be done, and to fix a standard of purity, with such observations as may be deemed necessary.

I am, &c.,
(Signed) E. Burstal,
Secretary.

H. Letheby, Esq., M.B., F.L.S., &c.,
London Hospital.

Ditto to E. Frankland, Esq., F.R.S., &c., Royal College of Chemistry, 315, Oxford Street.
Ditto to Dr. Odling, Bartholomew's Hospital, E.C.

Report on the Treatment of Sewage for Purposes of Defæcation, and on the Quality of Defæcated Sewage Water that may be permitted to enter the River Thames.

(*Received 4th March* 1868.)

Gentlemen,

In accordance with your reference of the 6th August last to the effect "that we would report to you whether "fluid which has been mixed with sewage can be so purified as to be admissible into the river Thames, and if so, "in what manner it can be done, and to fix a standard of "purity, with such observations as may be deemed necessary," we beg leave to report to you that we have visited the towns of Croydon, Rugby, Carlisle, Worthing, Leicester, and Hertford, for the purpose of ascertaining what are the practical results of the defæcation of sewage by irrigation, and by precipitation with lime, and we find that in respect of the former treatment of the sewage the operation is very successfully performed at Croydon, where the sewage from the outfall at Beddington, amounting, as we are infor med, to from 2,000,000 to 5,000,000 of gallons per day, is, after being filtered through shingle to keep back the coarser matters, distributed by means of open channels upon about 370 acres of land. The land is very porous, consisting of a subsoil of coarse gravel, and the crops raised upon it are chiefly rye grass, which is used for the most part in a green condition for feeding cattle. The water discharged from the land after irrigation and percolation through the soil is remarkably improved in quality, and may, we think, be safely discharged into any running stream.

At Rugby, Carlisle, and Worthing the processes of irrigation were not such as to enable us to form a very positive opinion of the quality of the outfall water, as it disappeared to a large extent into the ground; but the samples which we were able to collect were so far free from objectionable quality that they might safely be admitted into a proper volume of running water.

The sewage from one district of Croydon is discharged upon clay land at Norwood, and except in this instance and perhaps also at Worthing the soil appeared to be especially well suited for the reception of sewage by irrigation, for it was so porous from its sandy or gravelly nature that the water freely percolated it and was thus easily defæcated.

The conditions in fact which appear to us to be most favourable for defæcation of sewage by irrigation are:—

1st. A porous soil with good subsoil drainage.

2d. An outfall into a moderately large volume of freely running water; as, for example, a volume of not less than eight or ten times the volume of the defæcated sewage water.

3d. A considerable area of ground, in order that in times of heavy rain and during the growth of crops there should be ample means of disposing of the sewage. The area for the reception of the Croydon sewage at Beddington appears to be sufficient for the purpose, and it amounts to about 80 acres per 10,000 of the population.

The second process for defæcating sewage by treatment with hydrate of lime we saw in operation at Leicester and at Hertford. It consists in the addition of from 12 cwt. to a ton of lime, in the condition of a thin liquid, to each 1,000,000 gallons of sewage; and at Hertford there was also used about 50 lbs. of chloride of lime. The sewage mixed with lime and well agitated was permitted to flow through long subsiding tanks, where the suspended matters settled; and at the end of the tanks the clear water ran off

Capt. E. Burstal.
18 March 1868.

by a weir which was only a little below the surface of the water. By this process the sewage was deprived of its suspended and of a considerable portion of its dissolved matter; but, as in the last case, it was necessary that the defæcated sewage should be received into a considerable volume of running water, to prevent a secondary putrefactive change. At Hertford the defæcated sewage water is filtered through coarse sand, and it runs a distance of nearly a mile before it enters the river Lea. We remarked that although it left the filter a little turbid from suspended lime, yet it became clear after it had run about a quarter of a mile in the conduit.

In the performance of this process of defæcation we are of opinion from the results obtained at Leicester and Hertford that,—

1st. The proportion of lime should not be less than one ton, and that there should also be used 56 lbs. of chloride of lime per 1,000,000 gallons of sewage.

2d. That the mixture of the sewage with the lime and chloride of lime should be very complete, and that the mixture should be agitated so as to aggregate the suspended matters, and thus assist in the subsequent precipitation of suspended matter.

3d. That the sewage when thus treated with lime should flow along two subsiding tanks in series; the first should be capable of holding at least an hour's flow of sewage, and the second of holding not less than four hours' flow. The tanks should be 4 feet in depth, and the overflow of the defæcated sewage should be by a weir only half an inch below the surface.

4th. That there should be a double set of tanks for alternate working.

5th. That the defæcated water should flow through a shallow open conduit of not less than a quarter of a mile in length before being received into a stream of freely running water of not less than eight or ten times the volume of the defæcated sewage.

With these general remarks we proceed to state what in our opinion should be the standard of purity for the defæcated water.

1st. It should be free from offensive odour.

2d. It should be free from suspended matters, or, in other words, be perfectly clear.

3d. It should not be alkaline to turmeric paper, nor acid to litmus paper.

4th. It should not contain per gallon more than 60 grains of solid matter, dried at 260° of Fahrenheit.

5th. It should not contain more than three-quarters of a grain of organic and ammoniacal nitrogen per gallon.

6th. It should not contain more than two grains of organic carbon per gallon.

7th. It should contain not less than one cubic inch of free oxygen in a gallon.

These particulars of the standard of purity are derived from the practical results obtained in the defæcation of sewage on a large scale, as shown by the analytical table in the Appendix, as well as from the smaller operations of the laboratory.

In conclusion, therefore, we beg leave to state in the reply to the specific questions submitted to us in your reference, that,—

1st. Sewage water can be so purified as to be admissible into the river Thames.

2d. That this purification can be effected by the process of irrigation or of chemical precipitation.

3d. That sewage water so purified ought not to exceed the foregoing standard of impurity.

(Signed) E. Frankland.
Hy. Letheby.
Wm. Odling.

P.S. The conditions under which fluid which has been contaminated with sewage may be admitted into the Thames, as prescribed in the foregoing report, will, I have every reason to believe, preserve the river from being offensive to the inhabitants upon its banks; but, whilst thus far agreeing with my colleagues, I wish it to be distinctly understood that, in my opinion, such fluid can only be safely admissible into the Thames on condition that the water is not afterwards used for domestic purposes. Neither by the processes of purification mentioned above, nor by any others of a practical nature, at present known, can water which has once been contaminated with sewage be, in my opinion, again rendered safe for human use.

(Signed) E. Frankland.

Properties and Chemical Composition per Imperial Gallon of Sewage and its Defæcated Water.

Places where obtained.	Original Sewage.								When defæcated by Irrigation.							
	Appearance.	Odour.	Total solid Residue. In Solution.	Total solid Residue. In Suspension.	Nitrogen. Organic and as Ammonia.	Nitrogen. As Nitrates and Nitrites.	Organic Carbon.	Loss in Incineration.	Appearance.	Odour.	Total Solid Residue. In Solution.	Total Solid Residue. In Suspension.	Nitrogen. Organic and as Ammonia.	Nitrogen. As Nitrates and Nitrites.	Organic Carbon.	Loss in Incineration.
			Grs.	Grs.	Grs.	Grs.	Grs.	Grs.			Grs.	Grs.	Grs.	Grs.	Grs.	Grs.
Croydon (at Norwood)	Turbid	Sewage	41·00	11·01	2·906	0·556	5·884	9·52	Turbid	None	58·19	1·98	0·678	0·601	1·164	4·00
Do. (at Beddington)	„	„	27·67	10·16	1·529	—	3·573	6·32	Clear	„	27·17	0·00	0·295	0·349	0·467	0·75
Do. do. for 24 hours	„	„	25·83	—	1·153	—	—	—	„	„	26·18	0·00	0·178	0·419	—	—
Rugby	„	„	43·30	9·82	3·594	0·220	10·823	10·58	Turbid	Slight	36·11	0·00	0·747	0·231	1·470	2·49
Carlisle	„	„	28·50	3·62	2·206	0·036	4·169	8·42	—	—	17·67	—	0·303	0·103	0·165	2·15
Worthing	„	„	30·33	4·38	0·296	0·338	2·393	2·37	Clear	None	40·67	0·00	0·114	0·340	0·598	1·25
Penrith	„	„	—	—	5·821	—	5·381	—	„	„	19·04	—	0·143	0·290	0·555	—

	Original Sewage.								When defæcated by Precipitation with Lime.							
Leicester	Turbid	Sewage	63·33	11·45	2·556	0·025	21·935	15·30	Opalsnt	None	48·33	4·54	1·591	0·193	2·350	5·31
Hertford at Works	„	„	25·00	1·42	0·739	0·026	0·760	3·22	„	Slight	28·33	0·43	0·725	0·091	0·855	1·42
Do. at Outfall into Sea	„	„	—	—	—	—	—	—	Clear	None	26·33	0·00	0·133	0·077	1·085	—

Thames Conservancy Offices,
41, Trinity Square, Tower Hill, E.C.,
March 5, 1868.

Dear Sir,

I have to request that you will inform me whether Dr. Odling and yourself agree with Dr. Frankland in his opinion that the water of the Thames after receiving the sewage water, defæcated in the manner described by you, is unfit for human use.

I am, &c.,
(Signed) E. Burstal,
Secretary.

Dr. H. Letheby,
London Hospital.

17, Sussex Place, Regent's Park, N.W.,
March 6, 1868.

Dear Sir,

In reply to your letter of the 5th instant, I have to state that I cannot at all agree with Dr. Frankland that the water of the Thames, after receiving defæcated sewage water, is unfit for domestic use; for after a large practical acquaintance with the subject as it is observed in the principal streams and rivers of England, I have arrived at a very decided conclusion that sewage when it is mixed with about 20 times its volume of running water, and has flowed a distance of 10 or 12 miles, is absolutely destroyed; the agents of destruction being infusorial animals, aquatic plants and fish, and chemical oxydation.

I have stated this in evidence before Parliamentary Committees and Royal Commissions, and I am satisfied that the opinion is well founded.

I remain, &c.,
(Signed) Hy. Letheby.

Capt. Burstal.

Thames Conservancy,
41, Trinity Square, Tower Hill, E.C.,
March 9, 1868.

Dear Sir,

I have to request that you will inform me whether you agree with the postscript subjoined by Dr. Frankland, to the report made by him, yourself, and Dr. Letheby conjointly, to the effect that the water of the Thames, after

receiving sewage water defæcated in the manner described is unfit for human use.

I am, &c.,

Dr. Odling, (Signed) E. Burstal,
St. Bartholomew's Hospital. Secretary.

Laboratory, St. Bartholomew's Hospital,
Dear Sir, March 9, 1868.

From many considerations, and especially from the fact that the undefæcated sewage, &c., discharged into the Thames, above the source of the present water supply, is not recognizable in the water at present supplied, I am decidedly of opinion that the water of the Thames will not be rendered unfit for human use by receiving sewage water defæcated in the manner described in the joint report of Dr. Frankland, Dr. Letheby, and myself, unless indeed the proportion of such defæcated sewage water should become much larger than there is any reason to anticipate.

I am, &c.,

Capt. Burstal. (Signed) W. Odling.

6854. Have any steps been taken beyond giving notice to those towns?—The time stated in the notices, namely, 13 months, has not yet expired. I am not quite sure when the notice will expire, but I think it will be in May next.

6855. Have any of the towns acted on the notice which you have served, and are they taking any steps about intercepting their sewage?—Yes; I am given to understand that several of the towns have been taking active measures as to what should be done, and some have communicated with us as to the standard of purity of the water which is to be admitted into the river. The conservators have taken no steps to that effect, they only received the report which I have handed in a few days ago. They have considered it desirable that the Royal Commission now sitting should have that report, and they may probably wait until they get the report of the Commission before they take any decisive steps, or give any decided answer to those towns.

6856. From information which you have received, does it appear that the towns as a whole are inclining to the application of the sewage to the land or to deodorizing?—I think they have got both matters in consideration. I have heard that Kingston and Richmond, and that neighbourhood, are taking the thing in hand with the object of sending the sewage away altogether.

Capt. E. Burstal.

18 March 1868.

6857. At the expiration of the 13 months what steps will you take?—I cannot answer that question, because that must remain with the board; but one or two of the towns have applied for an extension of the time, considering that it is impossible to do the work within the time of the notice.

6858. The board have power, under the Act, have they not, to extend the time?—Yes, the board have power to extend the time for three years, that is the maximum.

6859. So as to give them time to carry out any works for the purpose of interception?—Quite so.

6860. Has any difficulty been raised in those towns as to the want of funds to carry out any general system?—They have not told us so. At any rate they have not made a complaint of that description in any communication made to the Conservancy Board.

6861. Has that been so at Reading?—We have had no direct communication from Reading, but there has been a pamphlet printed which shows the steps which have been taken by the Reading local board for the purpose of devising a scheme for deodorizing or getting rid of the sewage.

6862. Does your board intend to act upon the report which you have handed in of those three gentlemen as to the standard?—I cannot quite tell you that, because they have considered it right to send this report to you, and whether they will act upon it immediately or not I cannot tell. If the report of the Royal Commission should come out pretty readily, I think it is most likely that the Conservancy Board will take your report also into consideration along with that. They would consider that the evidence published with your report, and your report together, will enable them to form, perhaps, a better opinion upon the subject than the joint report of those three gentlemen. I merely say that that is their opinion, from what I have heard. There has no positive statement been made at the board as to that matter, but I feel pretty nearly sure that that is the intention of the board.

The witness withdrew.

Richard Meeson, Esq., examined.

R. Meeson, Esq.

6863. (*Chairman.*) Are you an engineer?—No, I am the proprietor of the chalk works at Grays, in which some very large springs are situated. I have worked them myself for a great many years. The water springs are situated in the chalk pits at Grays, in Essex, about a mile distant from the Thames. When undisturbed they rise to a height varying from about four feet to eight feet below Trinity high-water mark. The chalk had been worked out to the level of the springs over an area of about 60 acres when attempts to go deeper and get more chalk led to the discovery of a most abundant supply of pure water in about the year 1852. We employed five pumps to begin with; four 9-inch lifting and one 11-inch centrifugal, driven by two 8-horse and one 6-horse engines. The depth of water which passed over the gauge, which was 3 feet 8 inches wide there, was $5\frac{1}{4}$ inches, so that the quantity then obtained every 24 hours exceeded 2,100,000 gallons, besides that used on the works. This quantity was delivered daily, the engines being worked day and night, ceasing for only a few hours between Saturday evening and Sunday morning. During the week the water was lowered about 12 feet, and it then became possible to excavate the chalk to that additional depth over a small space; but when the engines ceased working the water speedily rose to its former height, and it occupied an entire day and night so to reduce the water as that work might be resumed; and throughout the entire remainder of the week the springs yielded the supply I have mentioned, which was all that the pumps then in use were capable of delivering. When a space of about 30 yards square has been excavated to a depth of about 12 feet, the pumps are overpowered by the increased pressure of water, and we have found that it would answer to begin in a fresh place 3 or 4 feet away, and by abandoning the first place, which still remains full of water, we have gone and pumped out of the other without disturbing the level of the first spring. We have had four or five of those pits sunk about 30 yards square, one after the other, leaving about 4 feet of chalk between them. These operations have been carried on now for many years, yet notwithstanding so large a quantity has been pumped daily into the Thames, no perceptible alteration has taken place in either the quantity or quality of the water.

6864. Is the water used, or is it pumped into the Thames simply to get rid of it?—It is now used. We supply Brentwood and Romford, and all the places between there. We have not got a demand for above 1,000,000 gallons daily now, although we supply the barracks at Warley. That is all pumped out of one small well about 6 feet in diameter, without interfering with the other water at all.

6865. I understand you to state that you could raise 2,100,000 gallons per diem?—We did do so; but now we are prepared to take contracts for 10,000,000 gallons a day at least.

6866. When you were raising 2,100,000 gallons you were obliged to rest, and you depressed your water level 12 feet?—Yes.

6867. Had you to rest 24 hours in order to regain

R. Meeson, Esq.

18 March 1868.

the level?—No. When it was down that depth of 12 feet we could not reduce it that depth in 24 hours.

6868. But had you to rest 24 hours before you could keep it at the original height?—No, we only rested for a short time between Saturday and Sunday morning; the water kept at its original height.

6869. (*Mr. Prestwich.*) What is the greatest quantity that you have obtained from those springs?—The greatest quantity that we ever got rid of was 7,000,000 gallons a day, and that went on for about six months.

6870. Are we to understand that the pumping continued day and night for a month, and yielded that quantity every 24 hours?—Yes.

6871. Did that lower the water?—Not permanently; it was up again in a very short time.

6872. To what depth did the level fall during the time that that quantity was being pumped?—About 18 feet at the lowest point of all.

6873. When it was sunk to a level of 18 feet how low was it below the level of the Thames?—At the level of low-water mark. The level gauge stands there now.

6874. Have you any reason to suppose that when it fell so low there was any introduction of water from the Thames? Did the analysis of the water at that time show any variation in the quality of the water?—I have no reason to think so, because chalk water will not percolate at right angles to the fissures. Along the fissures the water will flow freely, but across them it will not.

6875. Was any analysis of the water made at that time?—Yes.

6876. Did the quality of the water at that time show any difference compared to what it was at other times?—We had three analysis, made at different times, and there was no alteration whatever in the qualities of the water.

6877. Have you the analysis of this water?—Yes.

6878. By whom was the analysis performed?—By Mr. Dugald Campbell and by Dr. Dundas Thompson, and I have also another analysis made for the West Ham Board of Health by Dr. Voelker, who did not know where the water came from.

6879. (*Chairman.*) Will you put in those analyses?—Yes.

The same were delivered in, and are as follows:

REPORT on the CHEMICAL EXAMINATION of a SPECIMEN of the "GRAYS THURROCK WATER," UNFILTERED, by MR. DUGALD CAMPBELL, F.C.S., Analytical Chemist to the Brompton Hospital, &c.

The total solid contents per imperial gallon of 70,000 grains at 60 degrees Fahrenheit were found to be 26·88 grains, consisting of—

Mineral matter	25·36 grains.
Volatilized matter	1·52 ,,
	26·88 ,,

The mineral matter, on examination, was found of the following composition:—

Silica	0·96 grains.
Carbonate of lime	15·33 ,,
Sulphate of lime	1·13 ,,
Nitrate of lime	1·67 ,,
Carbonate of magnesia	1·47 ,,
Chloride of sodium	2·57 ,,
Carbonate of soda	0·68 ,,
Sulphate of potash	1·55 ,,
	25·36 ,,

Degrees of hardness by soap test, 16·6.

The volatilized matter does not blacken in the process of expelling it, consequently it does not exhibit the presence of any animal or vegetable substances.

When the water is boiled for a short time its hardness is very much decreased, and I found it then to be 5·85 degrees instead of 16·6.

ANALYSIS WATER from the SPRINGS AT GRAYS, ESSEX, by ROBERT DUNDAS THOMSON, M.D., F.R.SS. L. & E.

When subjected to quantitative analysis it yielded the following composition, per imperial gallon, in grains:—

Volatile matter	1·60
Silica	1·60
Sulphate of potash	1·30
Sulphate of lime	·95
Carbonate of magnesia	·96
Carbonate of lime	16·13
Carbonate of Soda	·30
Nitrate of lime	1·23
Chloride of sodium	2·33
	26·40 grns. per gal.

The chalk present in solution gives the water 16·13 degrees of hardness, which could be removed by the liming process of Dr. Clark.

ANALYSIS by Dr. AUGUSTUS VOELCKER.

An imperial gallon on evaporation left dry residue (dried at 260° F.).

	Grays. No. 1.	E.L.W.W. No. 2.	No. 3 West Ham Distillery Well.
Solid residue per gallon	27·05 grs.	23·80 grs.	*23·50 grs.

* 1·15 grains of this residue was finely suspended matter.

The analysis of the solid matters in the three samples of water yielded:

——	No. 1 Grays.	No. 2 E. L.W.W.	No. 3 Well.
Loss on gentle heat	1·29	1·80	·85
Oxides of iron and alumina, and traces of phosphorine acid	traces	traces	·55 principally oxide of iron
Lime	10·36	9·12	4·59
Magnesia	·66	·83	3·02
Chlorine	2·21	1·36	2·31
Sulphuric acid	1·53	1·85	2·40
Nitric acid	1·73	·42	·02
Soluble silica	1·05	·50	·45
Alkalies and carbonic acid (determined by difference)	8·22	7·92	9·31
	27·05	23·80	23·50grs.
Oxidisable organic matter per gallon	·416	·71	·64grs.
Hardness, according to Dr. Clarke's scale—			
Before boiling	18⅔°	16°	15°
After boiling	6½°	4⅘°	9°

Uniting nitric and sulphuric acid with lime, and the rest of the lime and the magnesia with carbonic acid, and assuming chlorine to exist altogether as chloride of sodium, the three waters may be represented to contain:—

——	Grays.	E.L.W.W.	Well.
Oxide of iron and aluminum	traces	traces	traces
Nitrate of lime	2·44	·64	·03
Sulphate of lime	2·60	3·14	4·08
Carbonate of lime	15·32	13·98	5·19
Carbonate of magnesia	1·38	1·66	6·04
Chloride of sodium	3·64	2·24	3·87
Soluble silica	1·05	·50	·45
Oxidisable organic matter	·41	·71	·64
Alkaline carbonites and loss not determined	·21	·93	3·20
	27·15	23·80	23·50

Analytical Laboratory,
11, Salisbury Square,
Fleet Street, E.C., Dec. 10, 1866.

AUGUSTUS VOELKER.

6880. (*Mr. Prestwich.*) Have you any analysis of this water made by Dr. Frankland?—No, only by Dr. Thompson, his predecessor.

6881. I believe that Dr. Frankland's analysis shows some difference with those two analyses by Mr. Camp-

bell and Dr. Thompson?—I have never seen any analysis by him.

6882. (*Chairman.*) What is the degree of hardness of your water?—16·13.

6883. Have you applied Dr. Clark's system of softening to your water?—Yes.

6884. With what result?—It is reduced to 4·8, but it is not a permanently hard water, when boiled it is quite soft enough for anything.

6885. What do you reduce it to by boiling?—5·8. It is very much approved of for locomotives. The Great Eastern Railway Company take it at Brentwood for that purpose.

6886. (*Mr. Prestwich.*) Is the water clear at all times?—Always perfectly clear.

6887. (*Chairman.*) Are you permanently using Clark's process?—No; it is preferred without I should say, certainly for drinking it is pleasanter without the softening process, because it contains a very considerable quantity of carbonic acid gas.

The witness subsequently sent in the following letter:—

Ship "Lincolnshire," E. I. Docks,
October 17th, 1861.

I certify that the water contained in a cask marked K was taken out in the above ship from Grays, on 21st March 1861, in jars; that it was shifted into the cask on the line during our voyage to Melbourne, and is the same water as left Grays; that I tasted the water several times on the voyage, and always found it in good condition, and better water than I have before taken to sea.

G. E. Bulmer, Chief Officer.

The witness withdrew.

John Bravender, Esq., F.G.S., examined.

6888. (*Chairman.*) You are a land agent and surveyor residing at Cirencester, are you not?—I am.

6889. Has your attention been directed to the subject of the supply of towns with water?—It has.

6890. And to the capacity of that district to yield a supply for the metropolis?—Yes, it has, and for other purposes; for the local towns in our own neighbourhood.

6891. Can you state to the Commission the result of your investigations?—I believe the Commission have before them a paper of mine, and I wish to show the steps that I have taken which bring me to the conclusions which are therein stated.

6892. You reside, do you not, near to where the last witness has given evidence about?—Yes, close by him. I live in the town, and he lives about a mile from it.

6893. Did you hear his evidence?—Yes.

6894. Do you concur generally in it?—Not altogether. I differ from him in one respect. I do not think it necessary to take the water above the mills. I should recommend you to take it below the mills, before it arrives at the Thames. There are 10 or 11 mills on the river Churn, which flows through the town of Cirencester, and there are 10 or 12 mills on the river Coln, which runs through Bibury and joins the Thames between Fairford and Lechlade, and those millowners which he alluded to most likely would be the parties to form a very serious opposition to your taking the water of those rivers, if it were taken from the rivers above the mills.

6895. Do you agree with him as to the yield of the district generally, apart from the question of interference with the rights of the millowners?—Yes. From my own observation my idea is, that 28 inches of rainfall might be taken as the general average of the whole of what I call the district of the Upper Thames, that is above Oxford—he says 30. I have observed it myself for a long time, though I have not a gauge, and I believe that he has given a greater average than was shown by the gauge at the Royal A. College, some time since.

6896. How could you observe without the means of gauging?—From taking notice of gauges kept by other people, the register kept at the Royal A. College, for instance, to which I had access. I have not brought a register with me of observations, but speaking from memory I believe that he has given a higher result than has been taken elsewhere. I think the Cotswold Hills are situate 300 or 400 feet above his house, and a great deal of the supply from the Coln, the Churn, the Windrush, and the Evenlode, comes from hills much higher situated than where his rain-gauge is; I believe you will find that the higher you ascend the less the rain-gauge will show, and the lower you descend to the level of the sea the greater the quantity the rain-gauge will show.

6897. That will depend upon the aspect, will it not?—Perhaps it might to some extent, and particularly where the country is covered with woods. I only give an opinion; I know that some of his observations from his own gauge do not exceed 28 inches. I have written a paper which I believe has been placed before the Commission through the Earl of St. Germans.* I have been very much interested in this matter, and I wrote that paper and handed it to him, and I think he caused it to be placed before this Commission. My great object would be to show you the mode in which I have treated the subject, to satisfy you that there is something reasonable in the propositions which I have made in that paper.

6898. Does this paper contain additional information which you desire to lay before this Commission?—Yes; I have some additional matters to lay before you. I rely principally upon the ordnance map. I have examined the watersheds personally on the ground. I know almost every inch of the ground between Gloucester and Oxford, having for some purpose or other been called into almost every field in the upper vale of the Thames. I have been engaged for the poor-rate valuation and for other purposes to a very large extent, and you will find I have marked upon the ordnance geological map the districts which I have named in my paper.

6899. Can you state the result of your rainfall of 28 inches?—Taking the evaporation at 10 inches, and the absorption and waste at 9 inches, we have 9 inches of available water left, and 9 inches deep on a square mile will give 774,400 cubic yards per square mile, and this multiplied by 875 will give 677,600,000 cubic yards for the available water of the upper Thames watershed, or 1,856,438 yards, equal to 313,523,912 gallons per day. I should take the water above the junction with the Thames, after it has served all the purposes of the land, and after it has turned all the mills that are upon those streams. But it would be extremely desirable not to take it until an Act of Parliament has been passed to compel the small towns which are situate upon those rivers to keep their sewage out of them, and dispose of it as they are now obliged to do upon the line of the Thames. Our town of Cirencester is more than three miles from the Thames, and therefore we are not compelled to keep the sewage out of the Churn, but we are contemplating doing so; it is impossible to go on without. I think Mr. Brown is in error about the gravel bed at Cirencester. The gravel bed at Cirencester is entirely local, it has been brought down by denudation and there deposited upon the great oolite with the fuller's earth beneath. It is true that the Forest marble once covered the place, but it has been broken up at the time of the denudation and become mixed with this gravel, the clay forming a thin bed on the great oolite, and the gravel 10 or 12 feet thick above it. This enables the inhabitants to make wells about eight or ten feet deep, and they get a considerable quantity of water except in extremely dry seasons. Occasionally parties have found it impossible to get water in dry seasons from those wells, and the necessity has arisen for people to sink their wells deeper, and I and some others have gone

* See Appendix II.

J. Bravender, Esq., F.G.S.

18 March 1868.

deeper upon premises which belong to us in Cirencester. I know that the well on my premises is nearly 30 feet deep, and that it goes into the fuller's earth, and it is not at all dependent upon this gravel bed and has no connection with it whatever. I know that the well in the marketplace at Cirencester is from 26 to 30 feet deep, and I know that it pierces into the fuller's earth, and when those shallow wells become deficient a great many people make use of that well, and it supplies a very large quantity of water; in fact the supply from the fuller's earth is almost inexhaustible. The engine at the Thames head in the driest summer has never been able to exhaust the well there. The well is 64 feet deep, and Mr. Brown stated correctly that for months together the engine throws up more than 3,000,000 gallons into the summit level of the Thames and Severn canal every day. I visited this engine on the 6th of March 1864; it had been going for two years and had not been suspended any longer than for six hours during the whole of that period. There were then 26 feet of water in the well, and the engine was making no impression upon it. I visited it subsequently in a very dry season indeed, at the end of the same year, and I found that there was 9 feet of water in the well, and the engine was making no kind of impression upon it, although the country was dry and scarcely any water in any of the rivers or brooks.

6900. (*Col. Harness.*) You were only taking 3,000,000 gallons?—They were only taking 3,000,000 gallons.

6901. (*Chairman.*) And the water level was depressed 17 feet?—Yes, it was depressed 17 feet, and the engine could not depress it any lower. I will put before the Commission a plan showing the situation of the Thames head engine, the shaft and the well. It has marked upon it the depths pierced into the fuller's earth (*handing a plan to the Commissioners*). The dip is south-east, and you will observe that the Boxwell spring is situated in the parish of South Cerney, $4\frac{3}{4}$ miles south-east of the Thames head engine, at which point there is a considerable geological fault, which throws up an immense quantity of water from the fuller's earth. Two or three years ago the inhabitants of Cheltenham brought in a bill in order to obtain water for the supply of that town from this spring. I measured the spring on three or four occasions. It does not vary like some other springs; it runs not altogether summer and winter alike, but varies about 500,000 gallons between winter and summer. It gave out on the 6th of March 1864 1,500,000 gallons in round numbers per diem, and when I measured it, on the 8th of October in the same year, it was discharging 1,100,000 gallons, and that was the only water at that period which ran down the Thames. The whole of the water in the Thames besides this had become completely exhausted. In addition to my paper I have some observations which it may be proper to mention here. In the summer of 1864 the Earl of St. Germans decided on deepening and improving the Thames below and adjoining his property, with the view of obtaining a better outfall for the drainage which had been executed under my superintendence on the Down Ampney estate. This estate is situated near Cricklade, at the top of the upper Thames, and is bounded by the Thames from the town of Cricklade to near Castle Eaton, in distance more than three miles. In August of the year 1864 we found the water sufficiently low to enable us to commence the works, and on the 24th of that month we succeeded in confining nearly all the water descending the river into a definite space of 12 feet in width. I carefully ascertained the velocity and depth and found that 13,000,000 gallons were passing in 24 hours. This observation was made towards the upper part of Marston Meadow, about half a mile to three-quarters of a mile above Castle Eaton bridge. On the 13th of September the water passing down the river was confined to a width of $4\frac{1}{2}$ feet in another part of the river further up. The depth and velocity were carefully taken, and I found that about 7,000,000 gallons were descending in the 24 hours, the river having decreased nearly half in volume in 20 days. On the 8th of October the water passing down the river was confined to a width of 3 feet a little below the bridge at Water Eaton. I again carefully ascertained the depth and velocity, and found that rather more than 1,000,000 gallons were descending in the 24 hours. In the morning of this day I had ascertained that no water was passing down the Thames at the bridge at Cricklade (that was about a mile above); there was no water in the river there except in the hollows in the bed of the river in a few places. I examined the Churn, which flows into the Thames near Cricklade, and found it completely dry at South Cerney; and on descending the stream to where the water from Boxwell spring joins the Churn I observed a considerable quantity of water flowing into the Churn from Boxwell spring. On visiting Boxwell spring, about a quarter of a mile up the brook from this junction, I found it discharging about the usual quantity. I had some time before ascertained the flow of this spring and did so at this time, and found the discharge about 1,100,000 gallons in 24 hours. The fact is that the water passing Water Eaton was from the Boxwell Spring, and in passing over about three miles of porous gravel and somewhat peaty soil there was a loss of 100,000 gallons per day at that time. This loss would eventually find its way into the Thames lower down the vale. It may be observed that from the middle of August to the middle of October there was scarcely any rain fell, and that which did fall was absorbed immediately, and made not the least difference to the water in the Thames. Our observations extended over 45 days, from the 24th of August to the 8th of October, and during this period the entire supply of the Thames above Water Eaton ceased, except what was supplied by Boxwell spring. I might say that I have not only gauged Boxwell spring but I have taken the temperature of it, and I find that the water discharged from it is about two degrees higher in heat than the water in the canal not 10 yards from it, and in winter the frost does not freeze over the spring nor the brook for 200 yards below its source so soon as it freezes over in other places, and I have seen steam rise from the water in the winter time when it has issued from the spring. I called Dr. Voelcker's attention to this when he was at the R. A. College. The reason is this, that the water in the summer time when it is warm weather falls upon a large area of the upper oolite in a very warm state; it descends rapidly through the porous rock and comes on to the surface of the fuller's earth, and descending gradually for several months it issues from this spring at a higher temperature than the water on the surface, because the winter has come on the surface but has no effect below, and that is the cause of the difference in the temperature. Having alluded to the great loss in the Churn by passing over the porous rock of the under oolite, I may be excused in quoting a table of the results obtained in 1859, and I do so with the greater confidence because those results were obtained from a series of observations made by myself under the direction of Mr. Simpson, extending over a period of six weeks. At that time the millers complained very seriously of the loss of water from the Churn. I was concerned for two or three landowners and I told them what I thought was the cause; they hesitated in believing what I had to say. They thought that Mr. Hutchinson and Mr. Elwes, whose property lies upon the lias, were the parties who caused the loss of water, because the one had made a fish-pond and some ornamental water, and another was driving a saw-mill and diverting the water. They thought by those works they were deprived of the water. I believed that they were not, and in consequence of our difference of opinion I recommended them to call in some practical engineer, and Mr. Simpson was called in. When he sent down his assistant I went over the river with him and pointed out what I thought

was the cause, and after a minute inspection we decided upon placing on the river some sizes, and he left me and my assistants to measure the water for six weeks. We took it very accurately and made a return at the end of six weeks. He then made his calculations, and this is the result. I have with me a plan showing where all the sizes were put in and the discharge of each spring. The Seven Springs is a place about four miles from Cheltenham upon the road to Cirencester, and is the head of the river Churn. There the water is thrown out by the lias and it is the furthest tributary of the Thames. At the Seven Springs the flow was 11 cubic feet per minute. At a quarter of a mile below the springs the flow was 31 cubic feet per minute; at three-quarters of a mile below it was 61 feet; at one mile below it was 73 feet; at two miles below it was 105 feet; at $2\frac{1}{2}$ miles below it was 165 feet; at $4\frac{3}{4}$ miles below it was 312 feet; and at $5\frac{1}{2}$ miles below, estimated at the maximum, it was 320 feet. Then we got off the lias on to the rubble beds of the under oolite which were absorbing a large quantity of water, which I had pointed out before the observations commenced; but at this point the volume of the river instead of increasing began to diminish, for at $6\frac{1}{2}$ miles below the spring the flow had decreased to 290 cubic feet per minute; at 7 miles below it had decreased to 235 feet; at $7\frac{3}{8}$ miles to 179 feet; at $8\frac{1}{8}$ miles to 113 feet; at $8\frac{7}{8}$ miles to 45 feet; at $9\frac{3}{4}$ miles to 33 feet; and at $12\frac{1}{2}$ miles below it had decreased to 30 cubic feet per minute, almost absorbing the whole of the springs above. The loss of water in descending the Coln is much greater than the loss to the Churn, and I have no hesitation in stating that if this river (the Coln) was thoroughly puddled, as Mr. Simpson recommended, in 1859, in the case of the Churn, the Syreford spring, a spring which discharges 3,000,000 gallons in the course of 24 hours, and sometimes more, might be sent down to Cheltenham, and the abstraction of the water would not be felt at Foss Bridge, which is about four miles from Withington, where the lias terminates. Between Foss Bridge and Withington there is oolite in the bed of the brook which absorbs an enormous quantity of water. The inhabitants of Cheltenham tried to get this Syreford spring diverted into Cheltenham, but Lord Eldon and some others who had some mills on the river opposed it, and the inhabitants did not succeed. Mr. Simpson was engaged then for Lord Eldon, but it did not suggest itself to him that if this river were puddled they might safely take the whole 3,000,000 gallons into Cheltenham; it would have gone down to Cheltenham by the mere force of gravity, and might have been carried to the top of the highest building in the place. There has been a doubt as to the source of the spring called the Thames head, which is not far from the engine which I have shown upon the plan. It is an intermittent spring, that is, it only discharges at certain seasons when there is a large body of water descending the plane of the stratification of the fuller's earth; when it rises higher in the bed of oolite than the surface, it discharges; but whenever the water falls below that point the spring ceases to flow. The Rev. Mr. Clutterbuck appears to think the "Thames head" is derived from the Oxford clay, and I have for many years considered the watershed of the Forest marble totally inadequate for the supply of so large a quantity of water as is pumped up by the Thames head engine, and that the source of this spring must be the fuller's earth; and I believe Mr. Taunton agrees with me. Many persons in the neighbourhood have heard of a spring called "Winterwell;" this spring like that of the Thames head is an intermittent spring, that is, only sending out water in very wet seasons, and in dry seasons ceasing to flow altogether. Some years ago I had occasion to deepen a well in Winterwell bottom, not far below the spring just mentioned; this well was only 10 feet deep and had become dry; we sunk it 6 feet deeper and obtained an abundance of water, and have had plenty ever since. The summer was a dry one; all the materials which were brought to the surface I recognized as the shale and rough ragstone from the top of the fuller's earth. I was acquainted with the material, having previously sunk several wells into it, and always obtained an abundance of water. One well at the White Way, near Cirencester, is 65 feet deep, another at the Bowling Green farm, 30 feet deep, and my own well in Thomas Street, Cirencester, 27 ft. deep, and I succeeded one dry summer afterwards in getting it 3 feet deeper into the fuller's earth. The well in the market place at Cirencester is 26 feet deep, and this well has never been known to be entirely dry. It will be remembered that last autumn we had some wet weather, and being desirous of fixing the source of these intermittent springs, I invited Professor Morris, who was then lecturing at the Royal Agricultural College, to go with me to see those springs. We visited Winterwell spring first, and found it discharging an enormous quantity of water. This was on a Friday, and the occupier of the land informed us that "Winterwell broke out middle day on the previous Sunday." We left Winterwell and drove directly to the Thames head spring, which is situate on the south side of the canal close to Trewsbury quarry about half a mile west of the engine (which is mentioned on the geological map), where a quarryman lives. We inquired of him when Thames head broke out, and were informed that it was on the previous Sunday, showing as I think that the two springs have the same source, and continue to flow only while the rock above the fuller's earth is saturated up to a line above the surface. The surface at Winterwell spring is 20 feet above the fuller's earth, and that of the Thames head a little more. I think Mr. Taunton says 29 feet, but I have been unable to ascertain this myself. Those remarks on springs are incidentally introduced, but at a future period I may return to this subject, and the springs of the upper Thames watershed and their volume will afford abundant matter for a thorough investigation. Those are the remarks which I wish to add to the paper which I have already sent to the Commission. I have some observations of the watershed giving my opinion as to which are the beds which absorb water and which are the beds which do not absorb water or very little.

6902. All we desire is to ascertain the amount of rainfall, and the area and probable quantity flowing off into rivers which would be available for a water supply?—Then I will put it in.

The same was delivered in, and is as follows:—

Remarks on the Geological Strata of the Upper Thames.

In the Thames watershed we have the lias, under oolite, fuller's earth, upper oolite, forest marble, cornbrash, kelloway, and Oxford clay, on the north of the Thames.

The Oxford clay, coral rag, coralline oolite, Kimmeridge clay, Portland oolite, lower greensand, gault, upper greensand, and the chalk to the summit of the chalk hills, on the south side of the Thames.

The following are porous, and absorb a large quantity of the rain as it falls.

Under oolite.	Coralline oolite.
Great oolite.	Portland rock and sands.
Cornbrash.	Greensand.

Sandy beds of Forest marble and the chalk.

A great portion of the rain runs off the following strata as it falls:—

Lias - - -	A great portion runs off, except where covered with diluvium.
Fuller's earth - - -	Nearly all runs off; area very small.
Forest marble - -	Part absorbed by sand beds, and about one-fourth of the remainder runs off.
Oxford clay and kelloway.	Part runs off and part is absorbed by the surface gravel; but the whole, or nearly the whole, of the water of the Oxford clay reaches the Thames.

J. Bravender, Esq., F.G.S.

18 March 1868.

Kimmeridge clay	- A considerable portion runs off.
Gault - -	- Greater portion runs off, but partly absorbed again by the lower greensand.

At the head of the Churn, Coln, Windrush, and Evenlode, the under oolite has been cut through on the south and south-east side by denudation, which is the means of bringing to the surface a large quantity of the water which falls on the under oolite above. Without this denudation the vale of the Thames could not receive any of the rainfall on the upper portions of the under oolite; nor could any of the rainfall on the fuller's earth reach the Thames but for this denudation, except what may be thrown out by means of faults. Like the water on the lias it would all quietly descend the slope of stratification and pass many feet under the Thames.

The fuller's earth is a thick bed of very retentive clay, and no water passes through it. It retains on its surface, beneath the upper oolite, an enormous quantity of water.

A very large portion of the rainfall of the great oolite and forest marble, particularly that which falls on the sandy beds, descends through those formations to the fuller's earth below, and thus accumulates the enormous quantity there found, part of which, fortunately for the country at the head of the vale of the Thames, is brought to the surface by means of geological faults, which form large and never-ceasing springs. The principal springs are—

Boxwell spring,
Ewen spring,
Ampney spring,
Bibury spring,
Ablington spring,
Winson spring,

and others. Also three intermittent springs, called "Winterwell" and "Thames head," and one opposite Trewsbury quarry also called "Thames head."

The fuller's earth is the source from which the "Thames head" engine supplies the Thames and Severn Canal on its summit level with most of the water. There is a conduit which conveys a portion from the forest marble into the well at the engine, but this forms but a small portion of the supply. The engine pumps up three millions of gallons in 24 hours for months together in dry seasons without ever drying up the source, and I have no doubt of the capability of the fuller's earth at the head of the Thames to supply water for several more engines at the same rate, which would be sufficient for half a million of the inhabitants of London.

As the water on the surface of the fuller's earth in the neighbourhood of the "Thames head" could never reach the surface of the ground in summer time, no one could complain of the loss by pumping; but, on the contrary, an abundance would be brought to the surface, which would not reach it in that neighbourhood, and probably not in England, without pumping.

Complaint might be made in consequence of taking the water from off the forest marble, but this may be entirely avoided.

The whole of the rainfall of the Oxford clay and kelloway would find its way into the Thames between the western summit and Oxford. There are few, if any, springs, properly so called, in the Oxford clay. A great portion of it is covered with gravel and alluvial soil some feet thick, and the rain rapidly sinks through the soil and gravel down to the impervious clay, and thence escapes into the ditches and brooks, and thence into the Thames, without appearing on the surface in large springs. The body of gravel is not sufficient to retain it for any length of time, which is a necessity for a spring. A spring thus produced ceases soon after the commencement of dry weather.

With regard to the area of what I have called the Upper Thames, extending from Oxford up to the higher point of the watershed, it contains 875 square miles, and that watershed has at least 28 inches of rainfall; Mr. Brown at one end of it tells you that it is 30 inches; I have no doubt whatever that 28 is a reasonable estimate, and that you might take away one-third of that for evaporation and one-third for absorption and waste, which would leave 9⅓ inches of water available, but in my calculations I have only taken 9 inches.

6903. You state in that paper which you have furnished to the Commission, "The rainfall over this "875 square miles may be taken at 28 inches per "annum, from which 12 inches should be deducted "for evaporation"?—Yes, but when I want to make any calculations as to the available water I reduce it to 9 inches; there is the absorption beyond that, I do not found any calculation upon that, you will find that I make the calculation on 9 inches.

6904. (*Mr. Prestwich.*) Have you any other estimate of the rainfall besides that given by Mr. Brown?—No, I have not. I had a copy from the register taken for some time at the R. A. College, but I have mislaid it.

6905. This rain gauge of Mr. Brown I presume has been carefully kept?—Yes, during a period of 20 years, I believe. He is a very careful man, and he pays every attention to it. I have stated in my paper that in order to take the water and make reservoirs in certain places, there was an abundant fall between those places and Paddington; and to prove to you that I have some ground for making that calculation I will show the Commission an outline section of the Great Western Railway from Cheltenham to Paddington (*producing a section and explaining it to the Commission. See Appendix X*). The station at Swindon, where there might be a reservoir placed, is 250 feet above the level of Paddington. I propose to have reservoirs made at the mouths of the Coln, Windrush, and Ock, and that the water should be conducted down by the side of the Thames from the Coln to a place called Langley weir, and thence in a straight line, which would be nine miles across the country, to Didcot station. Then I propose that the water should be taken alongside the Great Western Railway to Paddington. This section which I have been showing the Commission is the original section which was handed over to me when I was engaged to purchase the land for the railway from Swindon to Cheltenham, and it exhibits the level of the rails, and I have taken the fall from that section. There is a fall of 1 in 1,320, or 4 feet per mile, between Swindon and Paddington. I have also a geological section of the line from the Sapperton tunnel. (*The witness described the construction of the tunnel and the geological formation of the ground.*) I have also brought with me a copy of the plan which was made in the time of Mr. Simpson, and an analysis which was sent me by Professor Church of the water from the Boxwell spring, and also an analysis of the water of the Seven Springs, which is said to be the head of the Thames, if they should be of any use to the Commission.

Witness handed in the following analysis of water, by A. Church, Esq., Professor of Chemistry at the Royal Agricultural College, Cirencester:

Boxwell Spring, taken 4th March 1868.
Temperature of water, 49° Fahr.

	Grains.
Total solid contents per imperial gallon - -	26·30
Loss on ignition, commonly called "Organic matter"	1·28
Carbonate of lime - - - - -	18·30

Seven Springs, taken Sept. 1, 1866.

Solid contents - - - - -	18·33
Lost on ignition - - - - -	0·83
Carbonate of lime - - - - -	11·83

6906. What is the sum total of those various springs which you have described; you have described Boxwell spring which gives a yield of above 1,000,000 gallons a day, and you say that the pump at the Thames head delivers 3,000,000 gallons a day; can you enumerate the other springs?—There is a spring at Ewen which gives the same as Boxwell spring, or a little more than 1,000,000 gallons. There is Ampney spring at Ampney Crucis, two miles east of Cirencester, which is thrown out from the fuller's earth by a fault, and which gives out an enormous quantity. It is very difficult to measure it because it comes out at two or three different places, but it all passes at one place near to a mill, and I gauged it there at 4,000,000 gallons in 24 hours, and in summer time about half that quantity.* Then there is

* The following was subsequently communicated by the witness:—"This was only *one* portion of the spring. I find in April /66 I "measured the entire flow near the mill and found it to be con-"siderably more than 20,000,000 gallons in the day; and yesterday I "visited this spring and carefully measured the flow of water, and "find that upwards of 30,000,000 gallons were passing the bridge near "the mill. I also visited Bibury spring and found it discharging "rather more than the one at Ampney Crucis."

a spring at Bibury which comes from the same source and which gives out about the same quantity. There is a spring about a mile above that at Ablington which I have also gauged, and that gives out quite enough to turn a mill; the discharge is more than 2,000,000 gallons. Then there is a spring above Winson from the same source which gives out about a million and a half. The Bibury, Ablington, and Winson springs are on the Coln, the Ampney spring is between the Churn and the Coln, the Ewen spring falls into the Thames at Ashton Keynes and does not get into the Churn.

6907. What are the limits of height above the sea within which those springs occur?—They are all about the same level as Cirencester, or a little higher, from 300 to 380 feet above the sea.

6908. Then it would appear that the sum total of those springs yields a larger quantity of water than you have stated to pass down the Thames near Cricklade?—Yes; the Coln comes into the Thames near Lechlade, which is a good way down the river.

6909. Did you not express an opinion that if water were taken from that district it might be desirable to take it at or near Cricklade?—Yes, about a mile and a half nearer to Cirencester than Cricklade. This would be from Boxwell spring, from Ewen, and from the Thames head.

6910. Has not your own evidence shown, and do not the observations which you have just made lead to the conclusion, that you would get more water by intercepting the water within a short distance from the springs themselves, because you have shown that many of those springs, after flowing over the porous strata of the oolites, lose a certain quantity of their water?—Yes, that is so, but in such case I contemplate the puddling of the under oolite. Then you might take the whole of that water which is saved by the puddling, and they would not feel it at all, even if you took it above the mills. The saving by puddling would be 3 millions of gallons per day. *J. Bravender, Esq.* 18 March 1868.

6911. Are you at all acquainted with the springs on the other portion of the watershed of the upper part of the Thames, such as those at the foot of the chalk downs?—Yes, I know some of them, they are by no means so strong and so large as ours. There is a spring up near Burderop which feeds the Swindon reservoir which supplies the canal. It is at the head of the Cole, which joins the Thames near Lechlade and passes Coleshill, the residence of Lord Radnor.

6912. Are you acquainted with any large springs in that district?—No, they are all of minor character.

6913. Has not the town of Swindon itself experienced some difficulty in getting a supply of water?—Yes, but it is isolated, it is situated on a hill above the level of the land around it. The town is upon the Portland oolite, and the reservoir is upon the clay beds south of the town. The reservoir is in the hands of a canal company. The town of Swindon is 100 feet above the railway station.

6914. Are there any springs near Ashbury and Little Hinton?—Yes, there are some springs up there, but they are not anything so powerful as ours.

6915. Have you had any opportunity of gauging the Thames lower down than Cricklade?—Not lower down than Castle Eaton.

The witness withdrew.

Adjourned to to-morrow, at 12 o'clock.

Thursday, 19th March 1868.

PRESENT:

SIR JOHN THWAITES IN THE CHAIR.

Alderman Sir BENJAMIN PHILLIPS.
Colonel HARNESS, C.B.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

RICHARD HASSARD, Esq., further examined. *R. Hassard, Esq.* 19 March 1868.

6916. (*Chairman.*) The Commission have received your letter written on your own behalf and on behalf of Mr. Hemans, pointing out certain evidence of Mr. Bateman's touching your own scheme, and expressing a wish to offer some explanation. It is desirable, of course, that you should confine as much as possible your evidence to those points which are in dispute. We do not want unnecessarily to limit you, but at the same time there are points which you have before touched upon in Mr. Bateman's scheme which you need not now revive. You will perhaps limit your remarks as much as possible to that which you have stated in your letter. Your first point, I see, is as to the provincial towns being at present amply supplied with water; what remarks have you to make upon that?—If you will allow me, before giving any further evidence I wish to make one or two remarks. I wish as much as possible not to take up the time of the Commission by going into any evidence which we have already given you, or by the repetition of evidence upon evidence. I presume that all the advantages which are claimed for the Welsh scheme as regards the benefits to be derived from soft water, constant supply, high service, and purity of water generally, will be conceded to our project; that all those advantages which apply to the one scheme apply equally to the other, and probably to ours in a greater degree on account of the greater purity of the water. But as regards the remark which Mr. Bateman has made upon the estimates of the lake project, and as regards the voluminous and tabulated statements that he put in of comparative estimates between the Welsh project and our project, as I only received the printed copy of his evidence yesterday at 5 o'clock in the afternoon, owing to the time occupied in getting it printed, I must crave the indulgence of the Commission to allow me to go into that part of the subject upon another occasion. I have not had time to analyse the evidence, and as Mr. Bateman has had several months to investigate the question and to prepare his statement, it is scarcely possible for me to reply to him in the few hours' notice which I have had. I shall take but very little time on a future occasion if you will allow me to go into it then.

6917. There are other points, I presume, which you can deal with to-day?—Yes, I am quite prepared with the other matters referred to in my letter, and I should think an hour on a subsequent day would be the outside that I should occupy the time of the Commission.

6918. (*Mr. Harrison.*) You would not go into matters which you have already dealt with in your previous examination?—Certainly not. I shall avoid as much as possible touching on anything which has been touched upon before.

6919. (*Chairman.*) Are you prepared to offer any observations upon your first point, namely, the ample supply of water to provincial towns?—Yes; with reference especially to towns in Lancashire, for as to the other towns, the Cheshire towns, the Potteries, and all that district, there has been no statement made to the effect that they are supplied properly with water. I have merely to say that all the hill gathering ground that is available in the south of Lancashire, where all the manufacturing districts are situated (they not extending further north than Preston,) is already fully occupied. The whole country is covered over with reservoirs, either for canal purposes, for mill purposes, or for towns supply. I had the honour of submitting to the Commission when I was last examined some maps of that district showing how the whole ground was occupied—more especially in the imme-

R. Hassard, Esq.

19 March 1868.

diate vicinity of Bolton—between Bolton, and Accrington, and Haslingden on the north, the whole country is cultivated, and a working coal-field; to the westward, the hill country is all taken up for the Rivington works, and all draining into the Rivington reservoirs. There is no hill ground except a small portion of Longridge Fell, which is occupied by the town of Preston, and used for the supply of that town, till you get nearly as far north as Lancaster. There is some small portion of gathering ground in the valley of the river Hodder, but that is mountain limestone, and the water is a hard water, which in that country is peculiarly objectionable. That limestone runs across until it joins the Leeds water-shed. The whole of the water in the district of Rochdale is appropriated for that town and for mills and canals. There are several reservoirs in that country at the head of the Rochdale canal. I have further to remark, with regard to this hill gathering ground, that when Mr. Bateman gave his evidence on a former occasion he stated, with regard to a certain area of the country in that district draining into the river Uddlesworth, that it was very improper that Liverpool should have been allowed to absorb it. These were his words, "I think that it was altogether wrong that Liverpool should have been allowed to go to this district, because Darwen, Accrington, Blackburn, Wigan" (which are large towns in that locality) "and many other places are large and flourishing towns closely contiguous to the Liverpool gathering grounds, the whole district having a dense population, where the inhabitants can only look to this little cluster of hills for a supply of water. Liverpool has put its paw upon the supply, and very considerably limited the power of the surrounding districts getting an additional supply of water, and I would venture to suggest, as it is a national question, that if Liverpool should be permitted to go to Bala Lake for water, where it may take water without injury to any manufacturing interest, those hills being as it were the great manufacturers of water, the Rivington district should not be absolutely given up as a supply, but should be held liable to have water abstracted from it for the supply of any neighbouring town which could not otherwise get a supply of water."

6920. Do you concur in that view of Mr. Bateman's?—I do, perfectly. I may state further that there is no gathering ground of sufficient elevation for those towns to be had south of Lancaster, and the difficulty of getting any additional supply of water for the towns in that district is now fully exemplified by the case of Liverpool, where the corporate authorities have been thinking seriously of going to the head waters of the river Lune, to Westmoreland itself, or to the mountainous districts of North Wales, localities distant from Liverpool 110 miles, 90 miles, and 85 miles, respectively.

6921. Following out your view and Mr. Bateman's with regard to the gathering ground appropriated to Liverpool, you are of opinion, are you not, that Liverpool might be supplied or partially supplied out of your general culvert?—Yes, our aqueduct will pass within 200 yards of the Rivington Works. I wish further to state that as regards Manchester itself, which has the reputation of being very largely supplied with water, if the same condition of things existed there which exists in other large towns of similar population, the authorities of Manchester would be now almost at the end of their rope. They would very nearly have exhausted their resources. In Manchester there is a very large quantity of water sold daily for trade purposes, about 7,000,000 gallons a day, I think it is producing a revenue of something like 64,000*l.* a year; and whether it is for the purpose of having more water to sell for trade purposes, or whether it is on account of the difficulty which has as yet been experienced in disposing of town sewage in large quantities, the authorities of Manchester have steadily set their faces against the introduction of waterclosets into the houses of the artizan class forming the bulk of the population of Manchester, and waterclosets there are the exception and not the rule. The privy and ash-pit system is adopted to an enormous extent in Manchester, to such an extent indeed that the corporate authorities actually own rolling stock on several of the railways centreing in Manchester just in the same way that a coalowner owns trucks, and those wagons are used for sending into the country daily the nightsoil cleared away periodically from the ash-pits of the labouring class, and you may see long trains of trucks going every day laden with it into the country.

6922. Is it your opinion that the authorities of Manchester object to a larger supply of water to that town?—No, I do not state that, I say that they have steadily set their face against the introduction of waterclosets.

6923. (*Mr. Harrison.*) Do you know the reason why?—I can only presume that it is either to sell more water for trade purposes, or on account of the difficulty of dealing with the town sewage.

6924. (*Chairman.*) You think that their idea is that by substituting waterclosets for cesspools, the volume of their sewage would be so increased as greatly to increase their difficulty in dealing with it?—That would form one of their reasons, and probably both would operate.

6925. Is that the reason in your judgment why they are not taking an additional quantity of water?—I think it very likely.

6926. The absence of waterclosets does of course diminish the consumption of water?—Yes, very materially. The quantity of water which the Manchester authorities can store on the mean of three dry years would be equivalent to about 33,000,000 gallons per day, and out of that they have to give 14,000,000 gallons for compensation, that would leave them between 19,000,000 and 20,000,000 gallons; probably about 20,000,000 gallons are applicable for trade purposes and for domestic consumption. Out of that they sell about 7,000,000 gallons daily for trade purposes, and that would leave them about from 12,000,000 to 13,000,000 gallons daily for the domestic supply of 600,000 people; and that is the extent of their resources.

6927. That would be how many gallons per head?—About 20 gallons per head, and they cannot get more than that unless they go to some further locality for additional gathering ground.

6928. And by means of your scheme you would give them an auxiliary supply?—Yes. With regard to the towns in the potteries, that large district containing about 200,000 inhabitants, there has been no question raised as to the inefficiency of their supply.

6929. When you gave evidence before, you expressed some doubt, did you not, as to Mr. Bateman's ability to form reservoirs as he suggested in some parts of his district?—Yes, in one particular portion of the district south of Llanidloes, an area of about 15,000 acres which is drained by the river Twylch, I stated that Mr. Bateman could not construct the reservoirs that he contemplated there because the valleys in which he proposed to make them were at that time occupied by a railway, and Mr. Harrison I think it was, said that he thought Mr. Bateman could scarcely have been unaware of the railway being there.

6930. Mr. Bateman has reported that fact to us, that he was not aware of it at the time?—I have no doubt I was perfectly correct in what I stated. Mr. Bateman says that he can construct a reservoir at a place called Babylon in that district which will answer his purpose equally well, but although a site for a reservoir undoubtedly exists there, it happens to be almost at the very head of the drainage area, and it would not command more than about 2400 acres out of the 15,000 acres comprised in the district, and therefore it practically would be of little or no value as regards the storing or the control of the water flowing off it. If you will allow me I wish just to make a statement on the subject of my evidence on a former occasion, as regards another reservoir in that southern branch of Mr. Bateman's scheme, the Trefeglys reservoir. I stated that owing to there being only one reservoir into which all the water both for the towns supply,

and for compensation, whether pure or turbid, must be collected and impounded, in my judgment filtration would at all events for that southern portion of the project be quite indispensable. However, Mr. Bateman thinks otherwise, and he has brought forward Loch Katrine, and adverted to it over and over again as an instance in which water although very highly-coloured I think he stated as brown as coffee, when it entered the loch, yet after exposure there for some time it is drawn off and conveyed for the supply of Glasgow in a state so pure that at a depth of 5 feet some quartz pebbles, perfectly white, appeared only as tinted with a very pale straw colour. But the case of Loch Katrine as compared with his proposed Welsh reservoirs, is totally different; and no comparison by analogy can in any way be drawn between them. Loch Katrine is a reservoir containing an enormous area of exposed water surface as compared with the area of country draining towards it. It also has an immense amount of exposed surface as compared with its storage, as there is only 7 feet difference between the top-water and the level at which the water is drawn off for the supply of Glasgow. I have prepared a table which I will put in shewing the area of Loch Katrine, and the ratio of its exposed surface to its drainage area and storage, as compared with the reservoirs proposed to be constructed for the Welsh scheme:—

The following TABLE shows the AREA of LOCH KATRINE, and the ratio of its Exposed Surface to the DRAINAGE AREA and STORAGE, as compared with the RESERVOIRS proposed to be constructed for the WELSH SCHEME.

Name of Reservoirs.	Drainage Area.	Area of exposed Surface.	Ratio of Exposed Surface to Drainage Area.	Storage in Cubic Feet.	Area of exposed Surface for each Million of Cubic Feet of Storage.
	Acres.	Acres.			
Loch Katrine	22,800	3,000	1/7th to 1/8th	910,000,000	3·3
Llanyddyn, Can Office. Nant-y-Eird and Rhyd-e-gro	66,380	2,645	1/25th	3,493,977,030	·75
Trefeglys and other Reservoirs	64,192	2,200	1/29th	3,215,573,522	·68

It will be seen by this table that Loch Katrine has a drainage area of 22,800 acres, and it has an area of water surface of 3,000 acres. Therefore the proportion of water surface to drainage area is between one-seventh and one-eighth, and as far as regards the towns supply, there is a difference between the top-water and the level at which it is drawn off of 910,000,000 cubic feet, and that gives an area of $3\frac{1}{3}$rd acres for each 1,000,000 cubic feet which is impounded in the loch. The northern branch of the Welsh scheme has a drainage area of 66,380 acres, and a reservoir surface of 2,645 acres. Therefore in this case the ratio of the surface of the reservoirs to the drainage area is only $\frac{1}{25}$th, that is to say they have only one acre of exposed surface for every 25 acres of drainage; and they have only three-quarters of an acre of exposed surface for every 1,000,000 cubic feet impounded in the reservoirs. And in the Trefeglwys reservoir which is the one I am particularly alluding to, they have less again. In the Trefeglwys and two smaller adjacent reservoirs, the drainage area is 64,192 acres, whilst the area of exposed surface is only 2,200 acres, being $\frac{1}{29}$th of the drainage area: that is to say one acre of exposed surface for every 29 acres of drainage, and they have only two-thirds of an acre exposed surface for every million cubic feet impounded, instead of $3\frac{1}{3}$ acres as you have in Loch Katrine, so that there is no analogy whatever between the two cases.

6931. Taking what we may call the bleaching area of Wales, is it your opinion that it would be insufficient to remove that colouring matter from the water? It would have some effect upon it, no doubt; but nothing like the effect that is produced in Loch Katrine. The area of Loch Katrine as compared with the drainage area is between four and five times as great as it is in those Welsh reservoirs. In Liverpool, where the water both for supply and compensation is impounded in the same reservoirs, filtration is found to be indispensable; and even then the objections raised against it on the scale of colour are so great that they have to mix it with water pumped from the new red sandstone.

6932. Mr. Bateman drew a contrast between the cost of forming reservoirs in the Welsh district, and the cost of deepening the natural reservoirs in the lake district, and of the several communications necessary to work your system. Have you anything to state upon that subject?—Yes. Mr. Bateman has given the cost of collecting the water and of constructing reservoirs in the Welch district at 1,060,000*l.* as against our estimate of 1,013,000*l.* for the same description of work in the lake district, which estimate Mr. Bateman does not dispute. But then in making that comparison Mr. Bateman has taken the cost of only one branch of his scheme, that is the northern branch, for supplying 130,000,000 gallons, and he has compared that with the whole expenditure which is to be incurred in impounding water in our scheme for the supply of 250,000,000 gallons daily. If we add to that the cost of collecting and impounding the water in the southern branch of Mr. Bateman's scheme, it makes a total amount of 2,200,000*l.* as against our 1,013,000*l.*, being a balance of 1,187,000*l.* in our favour.*

6933. (*Mr. Harrison.*) Are those Mr. Bateman's figures?—Yes, copied from his evidence. To institute a comparison between the two projects, of course, the cost of impounding in both branches of Mr. Bateman's scheme ought to be added to it so as to compare it with the total cost of ours.*

6934. (*Chairman.*) I suppose that nothing you can say will shorten the distance between the lakes and the metropolis?—I have something to say upon that. Mr. Bateman states that the district from which he proposes to take water is distant only 170 miles from London, whilst he states that ours is 270 miles, being a balance apparently of 100 miles in Mr. Bateman's favour. But in order to institute a fair comparison between the two, Mr. Bateman should have added the 23 miles of additional aqueduct which he is obliged to construct in order to bring in the water from his southern branch, which would make it 193 miles of aqueduct to bring the water from Wales, as compared with 270 miles to bring it from the lake district. So that although our locality is more distant than Mr. Bateman's, still the difference is not to the same extent as he has stated.

6935. What is the size of the tunnel in that 23 miles as compared with the main culvert?—Mr. Bateman's open aqueduct in the southern branch is 22 feet wide as compared with a width of 26 feet $4\frac{1}{2}$ inches in the main aqueduct, and the covered aqueduct has a width of 12 feet 6 inches as against 16 feet 6 inches in the covered conduit for the main project.

6936. Taking that view of the case you have 77 miles against you instead of 100?—Yes.

6937. Mr. Bateman estimates the cost of his works as against yours and charges you with the cost of 100 miles, but you reduce that by the explanation which you have given by 23 miles?—Yes.

6938. Namely, by reducing the estimate of distance as between you and Mr. Bateman to 77 miles?—Yes.

6939. Which will proportionately reduce the contrast which Mr. Bateman institutes between his scheme and your scheme?—Yes.

6940. (*Mr. Prestwich.*) That would apply, would it not, only to a part of Mr. Bateman's scheme?—The distance that a locality is away from a town virtually

* See explanations in questions 7159 and following.

R. Hassard, Esq.

19 March 1868.

depends upon the length of aqueduct that you have to construct in order to bring the water from that locality and therefore to make a fair comparison between the two projects you must add the length of that branch which is 23 miles to his main aqueduct and his other branch aqueduct.

6941. But that would only apply to one branch of his scheme ?—That is so.

6942. (*Mr. Harrison.*) It would be the difference between 23 miles of a full-sized culvert and 46 miles of a smaller culvert ?—That would be it.

6943. You branch off into two, and they are two of a very much smaller size ?—Not quite so much as you have stated, because the larger branch is not quite so long, but about 44 miles as against 23 miles.

6944. Then there is the difference between 44 miles of the small culvert and 23 miles of the larger culvert ?—Yes.

6945. (*Chairman.*) Have you anything further to add upon that point ?—Nothing.

6946. Then there was some question, was there not, as to the difference of fall between your scheme and Mr. Bateman's ?—Yes. There is no doubt that Mr. Bateman can give a greater fall to his aqueduct than we can. I do not dispute that for a moment, but I maintain that no great advantage of economy arises in consequence of that, because the fall which we have selected is that at which it is most economical to construct and to work works of that nature, and I shall show shortly that the fall which we have given to our aqueduct is such as to cause that velocity considered most advantageous in great works of this nature by all engineers who have had experience in the matter. It has been very largely adopted by Mr. Bateman himself amongst others. On the subject of fall I would wish to mention that there is an error of about 20 feet in some way connected with the difference of level at which Mr. Bateman stated that he could deliver the water in London. He has given the falls of his conduits in his evidence, and he has stated that he could deliver in his reservoir in London at an altitude of 270 feet above Ordnance datum. There has been some error which will not materially affect the question, but there has been an error of about 20 feet in that. He draws off from the reservoir at Rhyd-e-gro, which is the lowest reservoir on the northern portion of his project at a height of 450 feet. From that to the junction of the two branches at Marten Mere there is 5 miles open conduit with a fall of 6 inches per mile—that is 2 feet 6 inches; he has 12 miles of covered aqueduct, with a fall of 14 inches per mile—that is 14 feet; and he has 2 miles of syphons crossing the Severn, with a fall of 5 feet per mile, which gives 10 feet, being a total fall on the northern branch of 26 feet 6 inches, and that deducted from the height at Rhyd-e-gro of 450 feet leaves a height at the junction of the two branches of 423 feet 6 inches. Then from Marten Mere to London for the main aqueduct he states that he has 75½ miles of open conduit at a fall of 6 inches per mile, being 37 feet 9 inches. Then he has 65 miles of covered conduit, with a fall of 14 inches per mile, giving 75 feet 10 inches, and he has 11½ miles of syphons, with 5 feet fall per mile, giving 57 feet 6 inches, making a total of 171 feet 1 inch, and that deducted from the 423 feet 6 inches, which is the height of the commencement of the main aqueduct, leaves 252 feet 5 inches as the height at which the water could be delivered at Stanmore, and not 270 feet, as he has stated. That error does not affect the question very materially, but Mr. Bateman took some credit for the particular height, and he stated that he could deliver water more conveniently from it to the existing reservoirs.

6947. Mr. Bateman stated that at your height you would be unable to deliver your water into the mains of all the companies; do you agree with him in that ?—That I shall come to presently, but he took particular credit for that height of 270 feet, as it enabled him to distribute very conveniently to all the service reservoirs of the existing companies.

6948. (*Mr. Harrison.*) There would be no difficulty, would there, in his so arranging his fall as to deliver it at that height ?—No, but it would be coming to something like our dimensions and our fall.

6949. What is your height ?—We deliver at a height of 232 feet 6 inches, and he says that he will deliver at 270 feet.

6950. (*Chairman.*) The next point raised by Mr. Bateman is a very important one, namely, that your wrought-iron tubes for syphons with a fall of 1 foot 8 inches per mile would be insufficient—have you any explanation to give of that ?—Yes, I have. In the construction of syphons the question to be considered is, not altogether the fall that you give them, but it is the velocity with which the water will pass through them, the fall being one ingredient only which causes the velocity. In a 4-feet pipe, with a fall of 5 feet per mile, such as Mr. Bateman contemplates for his works, each pipe would deliver about 2,320 cubic feet per minute, or about 20,880,000 gallons per 24 hours, and the water would pass through it with a theoretical velocity of about 185 feet per minute; and if we add 25 per cent. to each of those figures, as Mr. Bateman has done, owing to the excess which the Glasgow pipes were found to deliver over their theoretical quantity, it will give the water passing through a velocity of 220 feet per minute, and a discharge of 26,100,000 gallons per 24 hours. But an 8-feet pipe, with a fall of 1 foot 8 inches per mile, will deliver theoretically 7,560 cubic feet per minute, equal to 68,100,000 gallons per 24 hours, and the water will pass through it with a velocity of about 150 feet per minute; and if we add 25 per cent., as in the other case, we shall have a velocity of 187 feet 6 inches per minute, with a discharge of 85,125,000 gallons per 24 hours. Therefore, although the larger pipe has only one-third of the fall, still the water will pass through it with a velocity equal to about 6-7ths of what it attains in a smaller pipe with a greater fall.

6951. (*Mr. Harrison.*) That is a point which merely affects the question of estimate, because if you require to have two pipes there is no difficulty in getting the quantity of water through; it would be only a question of estimate arising upon it ?—Economy was one of the reasons why we contemplated the use of those large pipes. A cast-iron pipe, 4 feet in diameter and 1½ inches thick, which it would be required to be on the average for standing this pressure, will weigh per mile 1,888 tons.

6952. Did you not, in your former evidence, give your reasons for adopting wrought-iron in preference to cast iron ?—I think I only gave the discharge. I do not think I gave the cost, or that I gave the reasons for adopting the larger pipes. I do not think I stated anything about the comparative cost of the two, but if I did I will not go further into that point. I wish to say just one or two words upon the subject of coating the pipes with Portland cement. These were the reasons which Mr. Bateman gave why in his judgment it would not be successful. He stated that it would be necessary to wet the iron in the first instance, which would cause it to rust, and that the cement would then scale off and afford no protection to the pipes, and he brought forward a variety of reasons why in his opinion that must certainly occur; but as regards that I have only to say that it is one of those instances in which a little practice is worth a great deal of theory. We produced a pipe before the Commission which was coated in that way with a lining of cement 5-8ths of an inch in thickness. That pipe was made at Middlesborough-on-Tees, and was made for the purpose of this experiment. It was brought up to London and was lying about in one place or another exposed for a fortnight before the coating was put upon it. Since the time I had the honour of submitting it to the Commission, which is rather more than 12 months ago, it has been lying in London on an open wharf. It has been exposed to all the differences of temperature between great solar heat and extreme frost; it has been rolled off a cart; it has been kicked about in every way; and yet the

cement adheres now so closely that it is perfectly intact, so much so that you cannot detach it from the metal except by a hammer and chisel.

6953. Do you consider that the introduction of those wrought-iron pipes and this cement is an essential feature of your plan?—No, I do not, but I say that it would be a very great protection to the pipes. As regards the use of cement for protecting the iron, at a discussion which was held at the Institution of Civil Engineers on the strength of cements, the matter was fully gone into, and Mr. Rawlinson instanced a case in which he had used Portland cement for making a water-tight joint between two cylinders, used in sinking a well, one being sunk inside the other and that he used it successfully for making a joint under a 90 feet head of water. At that time it had been in operation about three or four years, and had been subjected to all the shocks consequent upon heavy pumping, and yet it had remained perfectly intact. And on the same evening Mr. Scott Russell stated that Portland cement was extensively used for lining the insides of iron ships to protect them from the effect of bilge water. He instanced a case where he himself had seen cement dug out of the side of an iron ship which had been put there 18 years before, and that the paint and the skin of the iron were as sound as when the cement was first placed there. I submit that that is a pretty strong proof of the applicability of the material for the purpose.

6954. It never has been practically applied has it to water pipes for any period of time?—Not that I am aware of. I may mention that it was the tenacity with which I had remarked that Portland cement adhered to the polished surface of a trowel if a bricklayer left it for two or three days without cleaning it, and the difficulty of detaching the cement from the polished surface of the iron, which induces me to think of it for this purpose.

6955. (*Chairman.*) Would the application of Portland cement as a lining to these pipes add much to the friction?—It would reduce the friction very materially, because the cement is as smooth as marble; it is as smooth as plasterers work, much smoother than the iron itself.

6956. How do you form the joint, do you grout it in?—The way that we propose to apply it is by rendering it inside after the pipes are in place. That was the way that that piece I mentioned was done. It was not done at the bottom first and then turned over, but it was done *in situ*. The inside was rough cast in the first instance, just as a plasterer does a wall with cement, and it adhered at once to the iron, and in the course of a few hours after that there was a coat of cement put on about $\frac{3}{8}$ths or half an inch thick, and then there was a fine finishing coat about $\frac{1}{8}$th of an inch thick put on after that, altogether a thickness of about $\frac{5}{8}$ths of an inch. As regards the applicability of wrought-iron for these purposes, all that I have to say is that it is used for works of the same nature. Mr. Bateman has used it in his aqueducts for carrying the water into Glasgow and Mr. Bazalgette has used it extensively in the aqueducts of the metropolitan main drainage. Some years since, I forget how many, but I think it was seven or eight years since, there was a wrought-iron pipe of 7 feet 6 inches in diameter and 1,300 feet in length laid down in connexion with the Croton works supplying New York with water. That has been in operation seven or eight years certainly. And two large wrought-iron pipes, each I believe 6 feet in diameter, (and technically called by the Americans flumes) for conducting water to two large turbines at Lowell in the United States, working under a head of 30 or 40 feet of water, and driving the machinery of a very large mill, were constructed either 29 or 30 years ago. I read a description of them some time ago, in one of the engineering journals, and made a note of it at the time. The water was conducted by two 6-feet wrought-iron pipes to those turbines, and the metal was quite unprotected. They had been recently examined at that time, and the wrought iron was found in very good condition, whereas the cast iron which formed the junction chambers of the wrought-iron pipes with the turbine case was completely eaten into holes.

6957. (*Mr. Harrison.*) Were they buried in the earth?—Yes, they were buried in the earth and subjected to the pressure of water internally, so that as far as regards wrought and cast iron in that particular case the wrought iron was much more durable than the cast iron. The Loch Katrine aqueduct into Glasgow has several wrought-iron tubes.

6958. In that case it is exposed and painted, is it not?—Yes; they are suspended. I do not know whether they are painted internally or not, but they are ordinary troughs for the conveyance of water. The pipes might be protected both internally and externally with cement.

6959. (*Chairman.*) Some question was raised as to the difficulty of forming your tunnel under Kirkstone pass; have you anything to remark upon that?—Mr. Bateman did not say that the thing could not be done, but he seemed to consider that the central length of $1\frac{3}{4}$ miles between the shafts was a most serious objection, that it would very greatly delay the completion of the scheme, and he instanced the length of time which was occupied in driving the tunnel leading out of Loch Katrine, although they had a number of shafts in it, and he seemed to infer that according to the rate of progress there, our tunnel would occupy such a length of time that it would be almost prohibitory. When I gave my evidence before, I referred to the Mont Cenis tunnel and gave evidence of the rate of progress during the years 1863, 1864, and 1865, and the rate of progress effected during the last two years. In 1865 it had attained an average of 5 feet 6 inches per day, at each of the two working faces, and since that time I have seen and examined the two published returns for the years 1866 and 1867, and the rate of progress effected during those two years has averaged as nearly as possible six feet per day at each of the two faces. At that rate of working, the Kirkstone tunnel would be pierced through in two years and five months after the shafts were sunk, taking 313 days as the working year. In that particular case, owing to the height of the mountain, you could not sink shafts; the summit is about 1,100 feet.

6960. Have you anything further to add upon that point?—Not on that subject.

6961. What observations have you to make upon the comparison between the cost of Mr. Bateman's scheme and yours involved in the mode of construction?—The same circumstances do not apply to both cases. For the first 120 miles of our aqueduct, from Ullswater southwards, it passes through a country abounding in building material of the very finest quality and in every way suitable for the purposes of the works; in fact, much of the aqueduct is excavated in the stone itself, and I maintain that no prudent engineer would discard that admirable material which is to be had upon the spot and at a very small cost, in favor of brickwork to be brought from some distant locality at considerable expense. That was not the mode of construction which Mr. Bateman adopted himself in the Loch Katrine works, or in his Halifax works; he there used as much as possible the material that he found upon the spot, and he takes credit to himself for having done so. Here are drawings of the Loch Katrine aqueduct (*producing the same*) and you will see that the works are almost entirely constructed with the rubble of the country itself. At Halifax where there is building material, all the conduits between the impounding and the service reservoirs are constructed of stone.

6962. (*Mr. Harrison.*) Do not you assume that he would avail himself of the material of the country, as every engineer must do?—Yes. But I was about to state further that from the Potteries to London we are pretty nearly similarly circumstanced with Mr. Bateman, and we there propose to use concrete and brick as he proposes to use concrete and brick for his aqueduct, and there is really no material difference between us. We use more concrete and rather

R. Hassard, Esq.

19 March 1868.

less brick, he prefers to use more brick and less concrete, but there is really no very great difference between us. It is only in the northern portion of the project that we propose to use the material that we find upon the spot. From the Potteries to London we pass through a clay country, and from the River Severn to London Mr. Bateman also passes through a clay country, and he cannot avail himself of stone.

6963. In the other portion of it he goes through a great deal of country where for some distance he has stone?—Yes; west of the severn he would have stone certainly, but that is but a comparatively small portion as compared with the whole.

6964. (*Chairman.*) Will you have the goodness to state your views with respect to the Edgware reservoir?—Mr. Bateman stated that at the elevation at which we propose to construct our reservoirs no sites for them could be found. Those two reservoirs of ours will contain together 500 acres.

6965. (*Mr. Harrison.*) Did you in your original scheme go to the same place?—Mr. Bateman proposed Stanmore; we proposed Edgware all along, and latterly Mr. Bateman has proposed Stanmore and Edgware, we neither take a house or a road, and we have every advantage that Mr. Bateman claims. Although Mr. Bateman stated that at the elevation at which we proposed to construct our reservoirs no sites could be found, I am satisfied that we should have no difficulty whatever in constructing our reservoirs.

6966. Have you taken the levels of those proposed reservoirs at Edgware?—I have not, but I am satisfied about it, and I see no difficulty in forming an estimate of the cost. There are a great many levels on the map by which I was guided.

6967. (*Chairman.*) Having regard to the site which you have selected for your reservoirs, should you be able to deliver water to the Maiden Lane reservoir of the New River Company?—I have got the height of their reservoirs from a map published by Mr. Milne showing the works belonging to all the water companies in London, and that reservoir was there given as at a height of 219 feet, and it was in order to be able to deliver into it that I was guided in determining the height at which we proposed to deliver at Edgware, so that either Mr. Bateman has made some mistake or Mr. Milne has made some mistake as regards the height of that reservoir. But even if it is as Mr. Bateman states, there would be no great difficulty in slightly altering the level of that reservoir and putting the houses on the highest service immediately in connexion with it in connexion with a reservoir just above on the same system. It might be a matter of some expense altering it, but that is a case which would not be sufficient to weigh in a scheme of this nature. Mr. Milne's height is 219 feet above ordnance, and Mr. Bateman's is 231 feet.

6968. (*Col. Harness.*) Have you both assumed the same datum level?—Yes, both the ordnance datum.

6969. (*Chairman.*) Is there any question as to the capacity of the reservoirs?—Mr. Bateman stated that the contents of our reservoirs are not sufficient, but we have taken just the same sum for their construction as he has, and we can consequently make them of the same capacity; they are on the same spot.

6970. (*Mr. Harrison.*) It does not follow that you can do it without having taken sections; it is quite possible that you might not be able to do it?—The hill is on the same slope all through, and there can be no difficulty whatever about it; there can be no material difference in the ground in both cases.

6971. (*Chairman.*) Are we to understand that the calculations to which you have referred will be ready by this day week?—Yes.

6972. (*Mr. Harrison.*) In the estimate which you gave originally to the Commission, after reaching the Edgware reservoir, what was the additional estimate for distribution as far as you could give it?—As regards the position of the reservoir I stated "About "a mile north of Edgware is the place where we "propose to construct the service reservoirs; we "should have them in duplicate, so that one might be "cleansed while the other was in use."

6973. What did you estimate from those reservoirs to the point of delivery to the different companies?—I do not think that that question was gone into at the time either by Mr. Bateman or by us, and the estimates that Mr. Bateman has given in have it as a subsequent calculation altogether. I do not think that either Mr. Bateman or ourselves contemplated anything further at that time than the reservoirs at that place. We have 500,000*l.* down for them, and Mr. Bateman had the same figure in his pamphlet. I do not think he gave it in his direct evidence. In ours we did not go beyond the construction of service reservoirs at Edgware. We considered that 250,000*l.* would be sufficient to construct the reservoirs, and that we should have 250,000*l.* for connexion with the existing works.

6974. Do you propose to adopt the same plan of connecting your reservoirs with the existing service reservoir as Mr. Bateman has described?—I have seen his statement so lately, only within the last two or three days, that I have not had time to think of it; but when I am giving evidence as to the estimates I will give some evidence upon that subject.

6975. In the Lancashire district you say, do you not, that many of the millowners have got their own reservoirs for supply?—A great many of them.

6976. But none of those reservoirs are of sufficient capacity to hold all the flood water?—Generally not.

6977. In fact the district there is similar to what most districts are when you come to make waterworks. You have to make provision for supplying them in some way; they do not absorb the whole quantity from the water shed?—They do not absorb all the water to be got off the district.

6978. Then the evidence this morning would go rather to express an opinion that the whole of the water of that Lancashire district is already used and could not be applied further?—The millowners' reservoirs are not sufficient to control the whole of the flood water, there is no doubt of that.

The witness withdrew.

Adjourned to Wednesday next at 12 o'clock.

Wednesday, 25th March 1868.

PRESENT:

SIR JOHN THWAITES IN THE CHAIR.

Alderman Sir BENJAMIN PHILLIPS.	THOMAS ELLIOT HARRISON, Esq.
Colonel HARNESS, C.B.	JOSEPH PRESTWICH, Esq.

Sir BENJAMIN BRODIE, Bart., examined.

Sir B. Brodie, Bart.

25 March 1868.

6979. (*Chairman.*) You are, as we all know, professor of chemistry at Oxford?—Yes.

6980. Has your attention been directed to the quality of water used for domestic purposes?—I have been much interested in the question of the drainage of Oxford, and it is through my connexion with the drainage question at Oxford that I have been indirectly connected with the water question, but I should say that otherwise I really have not paid any considerable attention to the subject.

6981. Have you considered the effect on the human system of hard and soft water?—No, not as hard and soft water.

6982. You state that your attention has been drawn to this subject mainly in connexion with the drainage of the town of Oxford, have you made any experiments as to the condition of the water where a discharge of sewage has taken place?—I have not made any direct experiments upon that subject; but I live on the river at Oxford, just by a place where, unfortunately, a great drain falls into the river, so that I have a daily opportunity of witnessing its effects.

6983. Where the sewage has been discharged into the river and carried down by the current for a few miles, have you observed a difference between the condition of the water at that point and the condition at the point of discharge?—There certainly is very soon a difference in the condition of the water. My house is only one or two hundred yards below the point where a large sewer is discharged into the river, and yet at my house the weeds freely grow in it, and I do not think that, except for the turbidity of the water, you would say that the river was impure.

6984. Do you know at all the relative proportion of sewage as compared with the quantity of water flowing down the river at that point?—No, I do not; but occasionally you can see the sewage in the river.

6985. I presume it is a large volume of water as compared with the quantity of sewage?—There is occasionally a very large volume of water, but not always.

6986. It has been stated in evidence before this Commission that in the case of sewage discharged at Windsor into the river, and flowing down the stream six or seven miles, or rather more, at that point they have failed to detect the presence of the sewage, that from oxidization or the breaking up of the elements it is in such a condition that they have found nothing which in the judgment of the witness would be prejudicial to human health. Have you made any observation bearing upon that point?—I have not myself made any observations on that point, and, indeed, I do not know how such an examination could be satisfactorily conducted.

6987. A sample of water was taken out of the river immediately below the point where the sewage was discharged into it, and a sample was taken out seven miles below that point, and by instituting a comparison between the two waters, in the one case of course they could detect the presence of sewage, and in the other they failed to detect it?—The judgment of the witness on such a point could be of literally no value whatever, unless the method employed by him for the detection of the prejudicial matter of the sewage were really of such a nature as to justify him in pronouncing an opinion upon the subject. I do not know what the method employed for the detection of the sewage was and whether that method was adequate for its detection or not, but I may say with confidence that chemical methods for the detection of the sewage are extremely imperfect. Indeed I do not know of any adequate method for the examination of water for sewage.

6988. Have you formed any opinion as to the probable effect of the flow of seven miles upon water contaminated with sewage, whether at the end of that distance or any other distance it would be fit for human use, or could be considered to be a safe water?—The sewage would be during its course to a certain extent oxidized and destroyed, and resolved into other compounds, but how should we say that all the sewage is resolved and destroyed so that the water should be safe. To do that we must be able to apply some extremely sensitive test to the water which would enable us to ascertain the presence or the absence of sewage in it, and I want to know what the test is which we are so to apply. There are causes operating, as we all know, to destroy the sewage which, to a certain extent, will effect that end, but the question, as I understand it, is whether those causes are really adequate to destroy the sewage not partially, but absolutely and entirely, during a given course of the river.

6989. The question is, whether by the operation of Nature's own course, by the water flowing exposed to the air and becoming oxidised, the effect would be to free it from injurious elements thrown in in the shape of sewage, to such an extent as to render it fit for a supply of water for domestic purposes, and free from objections with regard to the health of the inhabitants?—I should certainly be sorry to pronounce a positive opinion either that the water was fit or was absolutely unfit for such purposes. Let us take an analogous case. Suppose that I were to take a glass of water and placing it before me on the table here, and I were to put into that tumbler of water a teaspoonful of sewage, perhaps one per cent. of sewage, and then I were to take, which I could easily do, an apparatus by which I should blow air through the tumbler of water, so as to effect its constant aeration, restoring to it the water evaporated, the question is at what time would that tumbler of water become in such a state that any one of us would be willing to drink it off, how many days, weeks, months, or years would elapse? That I understand to be the problem, and I am sure I cannot solve it; but I can only say that when you have once put sewage into the water I should be rather reluctant to drink it.

6990. You have made no experiments, have you, with a view to ascertain that poin t?—I have made no experiments to ascertain that point. I have seen accounts of experiments by others. I do not know what the experiment would be worth if it were made.

6991. You have been supplied with a copy of the medical evidence which has been laid before the Commission, and no doubt you have observed that we have had evidence on both sides, one party alleging that water impregnated with sewage will be purified by the action of the air and oxidisation in its course a few miles down the river, but on the contrary, Dr. Frankland states very distinctly, that water once contaminated with sewage is unfit for human use, and that you will still find what he calls the skeleton of sewage present, although it may have travelled 100 miles and been exposed to filtration?—I think what is asserted by Dr. Frankland is true, that there are no known causes in operation on which we can adequately rely to remove the sewage from the water. That causes are in operation which partially remove that sewage and diminish its injurious effects is true, but the question is whether those causes, as I said before, are adequate to produce a complete result; that is to say, whether they will take out of the water all the injurious matter which is contained in it, so as to render it fit for drinking. I do not think it possible, in the present state of our knowledge, to pronounce an absolute opinion upon that point. But if you ask whether it is wise to drink water into which you have put sewage, knowing that you have no positive means of getting that sewage out of it, that is a question which anyone can answer for himself, assuming always the injurious character of sewage. I am not now pronouncing any opinion upon that point, or saying in what degree sewage is injurious; that does not appear to me to be a chemical question. I think that is a question of very great importance, but which is much more likely to be solved by other agencies than by chemical experiments. Medical statistics will tell you more about the injurious or non-injurious character of sewage water than any analysis would do. It does not seem to me that we have, as I before said, any accurate chemical measure of the sewage in the water at all events, I do not know what that measure is. I have read the evidence which has been given by Dr. Frankland and one or two other witnesses also before this Commission, but I still hold to my opinion that we have no accurate measure of the sewage matter in the water, or even of the previous sewage in the water.

6992. Are you prepared to express an opinion on the result of the application of sewage to the land, the water being afterwards discharged into a river,

Sir B. Brodie, Bart.

25 March 1868.

whether it would or would not be injurious to health after its filtration through the soil?—No; I think here again the same obscurity prevails, only to a less extent. I think it is certain that the sewage-water must be benefited very materially indeed by being filtered through the land, and I have that opinion because I know that in the porous material of the land the processes of oxidisation which destroy the injurious sewage matter go on much more rapidly and efficiently than they do otherwise, and not only that, but that the land operates as a filter and stops, mechanically, a large portion of the solid injurious matter of the sewage; but if you ask me whether the water that runs out from the land, although it may be bright and clear, is a good beverage, I do not know how we are to answer that question except by giving the water to human beings to drink, and by long observation of its effects.

6993. Then, although the process of filtration may catch and retain all that is held in mechanical suspension, still in your judgment there may be elements passing off in solution that might be injurious to health?—I think there may be, certainly, and not only in solution, but even not in solution; I mean by that that there may be even solid matters, organic germs, which would be so small that they would pass through the filtering material employed.

6994. And which might be unobservable to the the eye?—Unobservable altogether to the senses, and yet which might be extremely detrimental to the health; but here again you cannot say that they are detrimental to the health, you can only say that they may be so.

6995. Has your attention been directed to the effect upon the water of coloring matter from the peat, or whether it is possible to get rid of it by exposure to the atmosphere, or any other mode of precipitating it?—I have not turned my attention to that subject.

6996. (*Mr. Prestwich.*) You have read the evidence of Dr. Frankland, and I presume of Mr. Wanklyn, with regard to the methods adopted for the determination of organic matter in water?—Yes.

6997. Those methods, no doubt, show the great improvements which have taken place during the last few years in the chemical analysis of water, but you think them still imperfect, with regard to the determination of the organic matters connected with the question of previous sewage contamination?—I think that they are imperfect both as regards previous sewage contamination and as regards actual sewage contamination. I ought to explain myself; Dr. Frankland's method really seems to do pretty well what is possible without inventing decidedly new processes. But one reason why I think that Dr. Frankland's method is to a certain extent imperfect is this, that the amount of nitrogen and of carbonate to be determined is altogether very small, and no adequate account is given of the errors of the method, so that I am not able to say from simply looking at the documents that I have had before me what the value of those analyses or those determinations is. To know what the value of an analysis is, we must know to what errors that analysis or method is subject; and I have not had put before me in this evidence, or I must have passed it if there, any statement of investigations of a sufficiently exact character as to the error of the method, which in this case is a point of fundamental importance. Now, this is not a matter which need be left in the dark, for I think it would be really possible to get at those errors. One very simple course would be to make not one or two analyses, but a large number of analyses of the same water, for it would be quite possible from a large number of analyses to infer what the error was to which the method was subject. And I think it would be a very good thing for the Commission to have placed before them some table of that kind indicating the probable error of the method.

6998. (*Colonel Harness.*) You mean in order to get at the probable error of a single observation?—Yes; a single observation tells me nothing at all. If a person tells me that he has found by analysis so much nitrogen as nitrates, and so much as organic nitrogen, I cannot tell simply from such a statement anything about it. I must know to what error that analysis is subject, that is, to what extent his statement is trustworthy, because it is possible, I am not saying that this is the case here, but it is possible, that the error may be even greater than the quantity of nitrogen to be determined, and I think it would be quite possible, as I say, for the Commission to get evidence upon that point.

6999. (*Mr. Prestwich.*) You mean by a given number of analyses being made of each sample?—I do not say that that should be done in every case, it would be very laborious to do it; but if you were to take one or two selected samples and have a great many determinations made of them, the more the better, you would then see, or at least you would have more chance of seeing than now, what conclusions you were really to draw from the analysis.

7000. (*Chairman.*) Are we to understand that the several analyses which you suggest to be made should all be made from the same water taken at the same time, or do you mean water taken at different periods?—I mean analyses of one and the same thing. Dr. Frankland, I believe, has to a certain extent investigated this error, as was pointed out to me just now, in a paper of his which was read before the Chemical Society, but as far as I understand his method it is not that which I suggest.*

7001. (*Mr. Prestwich.*) Would the analyses of the London waters which give the mean of a number of analyses made every month in the year be what you want?—No, that tells me nothing at all as to the point in question. If you tell me that water contains such and such a decimal per-centage of organic matter, that tells me nothing unless I know what value is to be attached to the observation, and one way of getting information on this point, which should not be neglected, would be to make a great number of analyses of one and the same water for the sake of trial by the same method and the same observer if you can.

7002. With regard to the method employed by Dr. Frankland, I presume it is most complete, and that he brings to bear upon it all the most recent and improved processes?—I imagine that to be the case. Certainly there is no more admirable analyst than Dr. Frankland.

7003. The way in which Dr. Frankland, in the tables which he has handed into the Committee, ascribes so much nitrogen to organic nitrogen and so much to other causes may, however, probably be open to a difference of opinion?—There are, un-

---

* The witness subsequently added the following remarks:—

The first series of experiments instituted by Dr. Frankland in elucidation of this point [Chemical Society, Quarterly Journal, vol. vii. p. 94] do not throw much light upon the question, for we can hardly argue from the determinations there given in the case of urea and of hippuric acid as to the probable error in the case of so different a material as sewage. The experiments, however, which are subsequently given [xii. p. 95] meet the case, and if sufficiently numerous and varied would give an answer to the proposed question.

The three series of experiments there detailed may be regarded as analyses of one and the same water, it being assumed (which is implied, although not stated,) that the same sewage matter was employed in the three series of experiments.

Thus regarded, experiment I. (100 Cl sewage, 900 Cl water) being taken as the starting point, the relative proportions of carbon and nitrogen in 100,000 parts of the water evaporated appear as follows:

Experiment.	Carbon.	Nitrogen.
I.	1·00	1·00
II.	1·09	1·00
III.	1·65	1·21

Dr. Frankland cites these experiments as tending to inspire confidence in the method employed. The divergence, however, between experiment I. and III. of 65·5 per cent. in the carbon and 21 per cent. in the nitrogen, is so large a proportion of the whole amount to be estimated, that, *from these data alone*, no reliable opinion could be formed as to the amount of sewage matter present. Experiment III. hardly justifies the assertion that by this method one part of sewage matter in 100,000 of water can be detected, since if experiment I. is to be assumed as the true result, in experiment III. the error is equal in amount to 0·65 parts of the whole carbon present.

doubtedly, several questions which give ample room for difference of opinion, there is the observation and the value that we are to attach to the observation, and even then it is a farther question how you are to interpret the analysis, supposing it to be correct.

7004. In all those analyses a certain value is ascribed to previous contamination, as determined by the presence of nitrates and nitrites in the water; will you give your opinion whether the presence of nitrates and nitrites is to be ascribed to that one source alone, or may it be ascribed to several sources?—I think the probability would be that the presence of a large quantity of nitrates and nitrites would indicate the previous presence of organic matter in the water; but I do not know that you could take that nitrogen, in the shape of nitrates, as an absolute measure of that organic matter, which is a different thing.

7005. I presume that when those salts are in large excess, there is little doubt that they may be ascribed to sewage?—It is, I should say, the most ordinary source of nitrates and nitrites.

7006. But is it not possible that in many cases such salts may be derived from other sources than that of previous sewage contamination, using that term in its common acceptation; may they not arise from other matters in the soil, and therefore is their presence a fair indication of previous sewage contamination?—I believe that nitrates may occur from other causes, but I cannot speak from positive experience.

7007. The main object to be sought for in water used for drinking purposes is not the presence of a small quantity of nitrates or nitrites, which would not be very important, but the presence of organic matter undecomposed; is not that so?—That would be, no doubt, the most important as well as the most difficult point to be determined.

7008. If you will turn to the table of Dr. Frankland you will see, in the column of the mean of organic nitrogen, that the quantities in the London waters vary from ·001 to ·011, and those in the waters from Lake Katrine, Manchester, and Lancaster, from ·001 to ·026; showing, therefore, little or no difference in the quantity of organic nitrogen. Have you paid attention to the conclusion drawn by Dr. Frankland that it is possible to determine the origin of this organic nitrogen by the proportion of organic carbon that may be in the waters?—No, I have not until now seen the tables referred to.

7009. Dr. Frankland considers that this organic nitrogen in the London water is of a different value from that in the lake waters, because the proportion of organic carbon to the nitrogen in the waters is different?—Yes. This appears to me a very important fact, and may really indicate that the organic matter in the water had, in the two cases, a different origin.

7010. Supposing that a certain quantity of organic matter were introduced into the water, it would only be a question of the length of flow of the river as to whether or not the sewage would be perfectly oxidised?—We know that the process of oxidisation does go on with very considerable rapidity under certain conditions of temperature, or in a porous soil; but, as I said before, how are we to say when that oxidisation is absolutely complete?—I do not know what crucial test you could apply to bring out that point, whether it is complete or not. The putting sewage into a river is a plain fact, as to which there can be no doubt; but what we do not know is, when you bring the sewage out of the river, and I do not see that any test has been given which is of a sufficiently accurate and delicate character to bring out that point.

7011. You think that the tests of the greatest delicacy are yet insufficient to determine the point at which sewage ceases to be present?—I may take a case which really is an absolutely analogous case to the case of water, namely, the case of the atmosphere. You may look at the atmosphere as really a great ocean. Gases from drains are being discharged into this gaseous ocean just as the water from the drains is going into the river. Those gases are so diluted when they get into the atmosphere that chemical analysis is absolutely impotent to reveal their presence in any given portion of the atmosphere. But nobody can doubt the injurious effect, under certain conditions, of the gases and other organic matters present in the atmosphere. Take the case of the Westminster drain, the opening of which is known to have occasioned a great outbreak of fever here. You say that you would not live in a house next it, nor at the end of the street, nor at the end of the next street; but where should you begin to live so as to be safe from the effluvia of that drain? We cannot answer that question. I suppose if I get to Oxford I am safe from that drain, but we have no chemical tests,—because that really is the only point at issue,—to apply to the air to say whether or not it contains injurious or poisonous organic matter from the drain. In the atmosphere just as in the water there are constant processes going on with great efficiency to destroy those noxious gases; and a person would argue, just as is done in the case of water, that you have sulphurous acid from the chimneys of London, you have the oxygen of the atmosphere, you have nitric acid, you have ozone in the atmosphere. All these agents, happily for us, are at work destroying those noxious gases from the drains and sewers and other places. But when is their work completely done? That is what we do not know. Another most important thing is this, that really there is no reason whatever to believe that the injurious character, either of sewage or of the gases from a drain, depends, fundamentally, upon the quantity of that sewage or of that gas, in all probability it far more depends upon the quality of the sewage, namely, what it consists of. Now what is the nature of the poisonous matter in the atmosphere or in the sewage? We do not know that at all. Therefore how can you possibly say when that poisonous matter is got rid of from the water or from the air. It is a question that with the means at our disposal it is absolutely impossible to answer; and I say, as I said before, that I think you have a much better chance of getting at these relations through accurate statistics properly applied, than you have through chemical analysis, because chemical analysis is one of the poorest things possible to reach those delicate quantities. You cannot get at those small quantities at all. Chemical analysis must be limited by our power of weighing and measuring; we can only do those two things. We can weigh and we can measure, and we can do that with a certain accuracy, and there we stop; but that accuracy is not capable of being multiplied *ad infinitum*. It may go on to a certain point, but we cannot go beyond that point. I think that it is impossible absolutely to answer those questions, for we have not the data; but the question arises, as I said before, whether a prudent person like to drink water which contains a certain quantity of nitrates and nitrites, or that when analysed is found to contain a certain quantity of organic carbon and nitrogen,—carbonate water into which you have deliberately put cartloads of sewage at some time or other in its course.

Sir B. Brodie, Bart.

25 March 1868.

7012. From the tables before us it would appear that the Thames water, when delivered into London, shows, independently of the presence of nitrates, which possibly may be ascribed to more than one source, a no larger quantity of actual organic matter than do the waters from the lake district, which come from purer and better sources?—This depends on the way in which we estimate the organic matter. However, even assuming that the ratio of the organic nitrogen to the carbon affords such a measure, it appears that the water supply of Preston from Longridge hills does not essentially differ in this respect from Thames water.

7013. But supposing that the water flowed a certain distance, whatever it may be, is there no limit beyond which you would say that the sewage would become innocuous?—General experience decides these questions for us, we do not decide them by scientific

Sir B. Brodie, Bart.

25 March 1868.

tests. We know very well that under ordinary circumstances these things do not kill people, because if so the poisonous effects of such water would have been found out long ago; but, as I said, it is not a scientific result, it is a conclusion of practical experience. I myself should never like to drink water into which sewage has deliberately been put, because I do not know when it gets out of it again. We know that it is put in, but we do not know when it gets out.

7014. Still that process of oxidisation is constantly going on in the soil and in the river, and therefore there must be some point at which the perfect destruction or oxidisation of this animal matter must take place?—What I think is much more important still is another point, namely, the great dilution of the material, and I should rely upon the dilution quite as much and more than upon the destruction of the injurious matter. Supposing the sewage of a large town such as Oxford poured into the river, there are numerous feeders and tributary streams to the river which effectually dilute the sewage. The sewage is gradually getting proportionately less and less, and therefore its noxious character diminishes and ultimately disappears.

7015. Have you paid attention to spring waters?—Not much.

7016. Have you paid attention to the action of soft water upon iron and lead pipes?—I am familiar with the usual experiments upon the subject, but the difference of action of different waters on clean lead is certainly marvellous. If you take a pure distilled water, and put into that pure distilled water a piece of clean lead, the next day the pure water will be full of lead, you will see in the water a large quantity of crystals of carbonate of lead. But if you take water containing a good many salts (for instance, sulphate of lime,) not a trace of lead can be discerned, and there is no doubt that soft water more readily acts upon lead than hard water.

7017. Have you noticed that if you expose lead to those pure waters of Wales and Cumberland, the action on the lead is exceedingly different, in some cases being very powerful, and in other cases very slight, or no action at all?—I do not think it is known quite why one water acts upon lead and another does not, for it does not appear that all salts are equally efficacious in preventing this action. But it is the bright lead that is acted upon and not the tarnished lead.

7018. Have you known any cases where soft water has been used in towns and any ill effects have arisen from it?—No, I cannot say that I have had my attention turned to that subject.

7019. Do you anticipate that by taking the waters of Wales, or the waters from the lakes in Cumberland, and bringing them to London by a given length of pipes and aqueducts, there would be any change produced in the qualities of the waters by the time they reached London, either by the action of the metals over which they passed, or by their action upon the carbonate of lime in the mortar or in the rocks used in the construction of the aqueducts?—I should really think not; but even there, of course, care would have to be paid to select the proper materials for the conduits. It would be very unlikely that the water would be to any appreciable extent contaminated in the way you mention by passing from Bala to London.

7020. Do you consider that the water would be apt to take up any of the lime, and would reach London any harder in consequence of that circumstance?—You would have to consider what the material was through which the water was conveyed. If we suppose that the water was in brick channels, the lime could only come from the mortar and other cements which were employed. I should think it very unlikely to take up much, but such a thing could be tested. You could easily ascertain on a small scale how much it would take up.

7021. (*Chairman.*) Is it not the fact that the surface of stone or metal in the aqueducts becomes coated very soon?—No doubt generally; but not in the case of soft water. I think that soft water would always have a tendency to appropriate to itself the salts of lime, but I should hardly think that that would be a source of difficulty; however, it would be very easy to try that experiment. I mean you might take a quarter of a mile of pipe, or the description of channel through which you were going to convey the water from Bala to London, and pump water backwards and forwards through it, and analyse it and see whether it had taken up any lime or not, and what quantity. That is a question which might very easily be answered.

7022. (*Mr. Prestwich.*) Have you ever resided in a district where soft water was in habitual use?—I have frequently resided in the Welsh district in question, and I know it very well indeed, but not in the towns. At Oxford, as you are aware, our water is hard.

7023. Have you any reason to suppose that the use of soft or hard water as a drinking water produces any difference of effect upon health?—I cannot say I have reason to think so.

7024. Have you reason to suppose that the health of a district is independent of that?—I have no reason to think it to be dependent upon it.

7025. Is there not a want of direct experiment upon that subject?—Oxford is a place where the spring water is extremely hard, and injuriously hard for every purpose, but I never heard that it had been made out that Oxford was liable to any particular class of complaint from that reason. If it were so, I think it would have been discovered; but perhaps some physician from the infirmary might tell you to the contrary.

7026. Do they not use the Thames water at Oxford?—No, they do not use the Thames water now at all. They get it from a reservoir supplied, I believe, by surface drainage.

7027. Do you know the degree of hardness of that water?—No, I do not. I was speaking of the well water when I said that it was so very hard. The town supply is not so hard as the well water, but I have been in the habit of using well water.

7028. (*Colonel Harness.*) You have stated that it is very difficult to detect small quantities in the analysis either of the atmosphere or of water; how small a quantity of unconverted sewage could you discover to be contained in a given quantity of water?—I should not like to answer that question, because I should like to try that experiment for myself; but Dr. Frankland says that one part of sewage in 1,000 of water may be detected.

7029. Would it be a large proportion of the water?—It would be very difficult to detect a minute proportion of sewage, but what I meant to say was that, nevertheless, these minute proportions may be, although not necessarily, extremely injurious to health; and my reason for saying that is this, that we know that in the atmosphere minute proportions of organic matter which we cannot detect by any chemical agency, do set up and continue most important chemical changes, and so it is a perfectly possible and conceivable thing that a very minute proportion indeed of sewage in the water might be most extremely injurious to health. I say that partly from general experience, and partly because I have had occasion myself very frequently to observe the vast importance in chemical changes of what people so frequently pass by as inappreciable quantities of matter. Indeed, I have occasion to see more and more every day that minute portions of matter, which previously were not suspected at all to exist, exercise important influences on chemical transformations.

7030. In reporting upon a water which contains sewage, I presume you would not say that it contains so much sewage, but that it contains such and such ingredients which may or may not have formed part of sewage?—Yes, that is all, I should say, and that is obviously all that can be said. It may contain no injurious matter at all, or it may possibly be that the very little that has escaped destruction is injurious

matter—we are very much in the dark upon that subject.

7031. Then it might contain a considerable quantity of sewage without its being in the power of a chemist to say this thing or that thing is sewage?—He might say with very great probability, that it once had been organic matter. I think that the method which has been proposed by Mr. Wanklyn for the analysis of water, which is mentioned in the evidence before this Commission, may be available, perhaps, for the detection of small quantities of organic matter in the water, although I do not see how it can be used for the quantitative estimation of that organic matter.

7032. Was your attention drawn to the part of Dr. Frankland's evidence in which he alludes to having mixed a certain quantity of choleraic matter with water which he was examining?—Yes.

7033. What effect had that evidence upon your judgment?—It confirms what I said, namely, that you may have very minute portions of organic matter in the water which may be very deleterious indeed, and which, nevertheless, you cannot detect.

7034. Would you call the $\frac{1}{10000}$th part a very small proportion?—I should call it not a very small proportion, it is quite an appreciable and a real proportion.

7035. If water could contain the $\frac{1}{10000}$th part of foul matter, and you could not rely upon chemical tests for its detection, you would not call it a good drinking water?—Certainly not; that is just what I wished to observe.

7036. Has your attention been drawn to the analysis of sewage water which has been used for irrigation, and after passing through the soil has been returned to the river?—I have said all I have to say on that point.

7037. Referring to the analyses before the Commissioners, is the water, after being used for irrigation, very much better than the original sewage?—There is a good deal of alteration in the character of the water after passing through the soil—what is termed organic carbon in the one case, you see, is 1·104, and in the other it is 5·888, and the nitrates seem to be the same. I think the best test of the power of the chemist in this respect would be to put a number of analyses before a chemist who is possessed of full information on the subject, and let him from the analyses, without knowing whether sewage has been put into the water, say whether sewage had been put into the water, and how much. When he could do that with certainty, then you would be sure that he had discovered a method of determining the sewage. Do not tell him what the water is from which the analyses are made, but send him, say 100 analyses, and let him form his judgment from them.

7038. (*Chairman.*) Supposing he were to misread the result of his own analysis and to attribute to the presence of sewage that which might be attributable to some other cause, what would you say?—It is just the same whether he made the analysis himself, or another person made it; assuming the analysis to be accurate.

7039. (*Mr. Prestwich.*) What course do you consider the most efficacious one to get rid of sewage contamination from the towns on the river?—The best is not to put the sewage with the river at all, that is the best answer I can give, and indeed, that is really the only course by which you can be certain that you have not got it in. I certainly do think it a very good thing to employ the processes used for the filtration and destruction of sewage, and they are *pro tanto* beneficial. They really help the matter a good deal, but I do not think that they are entirely effectual. There is no known process that I am aware of for, on a large scale, destroying the injurious qualities of sewage.

7040. (*Col. Harness.*) By throwing it upon the land you absolutely get rid of a large portion of the sewage, and what is left is somewhat improved?—Very greatly improved, but I should not like to take a glass of water and drink it from just the spot where it went into the river, still less to make it one's daily and habitual beverage.

7041. (*Mr. Prestwich.*) If water is supplied to a town from a river which in a part of its course has received previous sewage contamination, and if that water is used on a large scale by that town and produces no ill results, and chemical analysis fails to detect anything unusual in its character, is it not a fair presumption that such water is wholesome and good water for the use of a town supply?—If it be used without injury to the inhabitants, really chemical analysis is altogether superfluous. But the question is whether it can be always and permanently so used. That seems to me to be the real point at issue. We should have found out long ago the injurious effects even of small quantities of sewage if the sewage were always injurious; but that is not asserted. It is only supposed that, under certain exceptional conditions, even sewage may become very injurious. The injurious character of a water impregnated with sewage matter might not be discovered for years. You might long go on using it, for years, and it might not be discovered, and yet you might have some outbreak of disease in the place which, nevertheless, might be connected with the use of that sewage water.

7042. (*Chairman.*) Then, under ordinary conditions, although you could not detect in the health of the inhabitants any injurious effect from the water, still if there are in the atmosphere increased causes of zymotic disease, the drinking of that water might ripen those causes to serious effect?—I can understand that, under certain conditions, the water which was uninjurious at one time might become injurious to the inhabitants; but what I was thinking of was, that the water, without being always poisonous, or always containing anything even detrimental might, under certain exceptional conditions, contain matter which would be very detrimental, and this might only occur now and then just as it is supposed to have been the case in the outbreak of cholera in the east of London. Of course the water in London must have been contaminated over and over again with sewage without cholera ensuing. I believe it has been mentioned in the evidence here that water becomes contaminated from broken sewage pipes; how many broken sewage pipes have there been in London during the last 10 years?

7043. (*Mr. Prestwich.*) You consider then that with regard to the effect of water upon the health of the inhabitants, it is rather a question for the medical observer than for chemical analysis?—I really think so. I think that chemical analysis is not yet sufficiently advanced (whether it ever will be I do not know) to pronounce a decision upon the matter, and that you have a better chance of getting at the real connexion between the injurious matters in the water and diseases generated by those matters through statistical observations carried on upon a large scale than through chemical analysis. Statistics elicit relations of cause and effect on which you cannot deliberately experiment. You cannot poison people for the sake of trying the quality of water.

7044. (*Mr. Harrison*). Taking into consideration that London now is supplied from the Thames, and assuming the water to be well filtered, are you prepared to say that there has been any positive injurious effect from the Thames water produced upon the general health of London?—No, I certainly am not prepared to say that from my own personal knowledge and experience, but I do not know the facts sufficiently to pronounce an opinion one way or the other; it would require a very considerable examination of the evidence to enable me to do so. This is a question for physicians.

The witness withdrew.

W. A. Miller, Esq., M.D.

5 March 1868.

WILLIAM ALLEN MILLER, Esq., M.D., examined.

7045. (*Chairman.*) You are, as we all know, professor of chemistry in King's College?—Yes.

7046. Have you directed your attention for some time to the quality of the water of the several companies supplying the metropolis?—I have had occasion to do so for many years past.

7047. Have you formed any decided opinion as to the value of soft water, as compared with hard water for domestic purposes?—There is no doubt that soft water, for all purposes excepting for dietetic purposes, is preferable to hard.

7048. Or for purposes of manufacture?—For purposes of manufacture and for cleansing and ordinary domestic use it is preferable.

7049. Are you of opinion that the use of soft water would be a great saving in soap to the inhabitants generally for cleansing purposes?—There would be a certain saving, but I think that the amount of saving has been somewhat exaggerated in some estimates which have been made regarding it.

7050. You have seen the evidence upon that point which has been laid before this Commission, do you concur in that view?—Some years ago I was a member of a Commission for the purpose of examining into the supply of water to the metropolis, and we very carefully examined into that question of economy in the use of soap. With regard to the portion of soap which is destroyed, one degree of hardness may be reckoned to destroy about 10 grains of soap per gallon, that is, supposing that the whole of that degree of hardness is expended in decomposing the soap. At that time, in 1851, that was the general conclusion at which we arrived.

7051. That was a Commission composed, was it not, of yourself, Professor Graham, and Professor Hofmann?—Yes.

7052. No doubt, although you may not concur in the precise quantity alleged to be saved in the consumption of soap by the use of soft water compared with hard, speaking generally there would be a considerable saving by the use of one over the other?—Undoubtedly.

7053. And probably the use of soft water for cleansing purposes would be beneficial to health?—Undoubtedly it is far more agreeable, as everybody knows, to use soft water than hard.

7054. Then as to the effect of soft water as compared with hard water on the health, apart from cleansing purposes, would the use of soft water promote the health of the inhabitants to a greater degree than the use of hard water?—Any precise observations are difficult to obtain, but I think, so far as observation goes, it is a matter of indifference whether it is hard or soft water.

7055. When you use the term "hard," you mean, of course, an ordinary and not an extreme degree of hardness?—Yes.

7056. Would 10 degrees of hardness in your judgment be injurious?—Not merely as hardness; it depends upon the quality of the hardness. Chalk waters, I consider, are waters which are perfectly wholesome, but waters which have a similar degree of hardness from sulphate of lime there appears to be some reason to believe are found occasionally to disagree with persons. Still there are waters which are supplied to large populations containing sulphate of lime, and very hard sulphate of lime waters. For instance, the population of Wolverhampton and Birmingham are supplied with water of this kind. It is certainly objectionable, but what I was going to say was that the evidence in that case is that there is no sensible injury to health directly traceable to the water as far as as observations go. I believe, generally speaking, the impression is that the hardness caused by sulphates of lime and magnesia is more likely to produce certain slight derangements than the use of chalk waters of a similar degree of hardness.

7057. You would have no doubt that water of something like 15 to 20 degrees of hardness might be used for domestic purposes?—I should not think there was the slightest reason to suppose that any injury would result from such water.

7058. Then you attach no value for drinking purposes to soft water over hard?—From long habit I should certainly prefer hard water for drinking purposes to soft water.

7059. With regard to the condition of the water from the Welsh and the lake districts when discoloured by peaty matter, could that peaty matter be removed by exposing a larger surface to the action of the atmosphere, and bleaching it, or would it be precipitated; and secondly, if still present in the water, would it act injuriously upon the human system?—I believe that it has no injurious effect upon the system, and it also is partially deposited in the storage reservoirs—it becomes oxidised and rendered insoluble.

7060. When conveyed through a culvert from either the one district or the other, in the course of its passage to London a large portion of the colouring matter would be destroyed, would it not?—That would very much depend upon whether it was an open or a closed culvert.

7061. It would be partially closed and partially covered?—I have no special facts upon that point; that is a question for engineering observation, I think.

7062. With regard to the presence of sewage in water you have heard the questions which have been put to Sir Benjamin Brodie, are you of opinion that, supposing sewage contamination to exist in water at point A and the water to travel from there to point B, a distance of from five to seven miles, that the sewage contamination would be destroyed, that the oxidisation will go on and break up the original elements of the sewage, and that it would not then be present, or that if present it would not be injurious to health?—I know that it is partially destroyed, but I cannot say what distance would be necessary to destroy it. I have no observations to enable me to say, nor do I think it would be an easy thing to devise any accurate observation which would prove it.

7063. You have examined the water of the Thames, I believe, frequently?—Yes, very frequently; one summer I was examining it every week.

7064. Did you, in the several analyses which you made, detect the presence of sewage?—Yes, very largely. At that time, the body of stream water in the Thames was exceedingly scanty; the sewage oscillated backwards and forwards, and formed a sort of black inky liquid, and with each turn of the tide it kept oscillating backwards and forwards in a short distance.

7065. You are now speaking, are you not, of that part of the river which is subject to tidal influence?—Yes.

7066. What was the state of the water at that part of the river above Teddington lock where the water companies are now taking their supply?—Above Teddington lock the water was very good, even at that time when there was but a scanty supply of water in the river.

7067. What year do you refer to?—I am now referring to the year 1859.

7068. Did you detect in the water taken from above Teddington lock the presence of sewage?—There was organic matter, but I should not have called it sewage.

7069. Did you then form an opinion that it was traceable to sewage or partially traceable to sewage or to some other cause?—I did not specially determine whether it was sewage matter or what the origin of the organic matter was.

7070. Would there be a difficulty in determining whether the nitrates were due to one source or partly to one source and partly to another; for instance, the drainage of land, the manuring of farms upon the watershed, and the washing of the remains of the sewage into the river?—I do not think there is any means of determining what proportion of the nitrates

is due to the natural supply from the chalk springs, and what is due to the oxidised sewage. In fact there is no means of determining that. They exist exactly in the same condition in the water, and therefore a proportion of the nitrates may be due partially to the one cause and partially to the other, the proportions varying with accidental circumstances.

7071. Although you have made no special experiments as to the effect of the action of the atmosphere upon sewage mixed with a large body of water and travelling in a stream four or five miles, have you from general observation arrived at the conclusion that the condition of water for human consumption is very much better at point B than at point A higher up?—There is no question about it.

7072. You have seen the evidence of Dr. Frankland in which he refers to the presence of sewage in the form of skeleton; if the view which he takes is a correct one would the presence of that skeleton be injurious to health do you think?—I understand that merely as a figurative expression showing the existence of nitrates and ammonia in the water. Neither of those things in themselves in small quantities is in the least degree injurious. I am speaking now simply of them after they have been completely converted into that condition of nitrates or of ammonia.

7073. And you are of opinion that in that condition they would not be injurious?—They would not have any injurious effect, always supposing they exist in small proportions such as they appear to have been found in the analyses.

7074. You are aware Dr. Frankland takes a very strong view of the presence of that skeleton of sewage, because, in referring to certain wells used by the Kent waterworks company, where the water is pumped from a depth of 250 feet through the chalk, notwithstanding the filtration at that depth he still detects the presence of those skeletons of sewage?—That is to say, he finds nitric acid or nitrates, and he assumes what I think he is not justified in assuming, namely, that those nitrates are the result of the putrefaction, or rather of the decomposition of sewage matter. No doubt they are formed by that operation in a great number of cases, but to say that they are always formed so would be, I think, far beyond what the facts warrant.

7075. Supposing you found in a river in its ordinary course a quantity of nitrates and nitrites, do you think that if the water were filtered through gravel and through chalk a depth of 250 feet it would be possible still to find the presence of a form of sewage?—I object to the expression "a form of sewage." I should not say that it was a form of sewage. I should say that it is the result of the oxidation of substances containing nitrogen.

7076. But, using the language of a chemist, Dr. Frankland calls it a skeleton; that means a form at all events of some pre-existing body that is found in a certain condition?—I do not take it as a form of any pre-existing body; it might be due to a substance which is actually there, and as actually there it does not indicate danger to those who use that water.

7077. Nor would it point to its original condition as being a part of sewage?—Certainly not. I do not deny or doubt that in a great number of cases the presence of nitrates does indicate the previous existence of some organic contamination. The only difference between Dr. Frankland's view and mine is this, that he assumes, apparently in all cases, at least if I read his evidence aright, that nitrates invariably point to previous sewage contamination. I think that that is not justified by other observations. The experiments of M. Boussingault and others show distinctly that the formation of nitrates does occur where there can be no suspicion of previous sewage contamination.

7078. Supposing the sewage were applied to land in irrigation, what effect would that have upon the water which ultimately finds its way to the river?—I do not know that upon my own knowledge, I know it merely upon the reports of others; but according to those reports the water is very materially improved by the operation, the diminution in the quantity of organic matter is very considerable.

7079. You have not tested the water at Croydon, after the sewage has been used for irrigation?—No, I have not.

7080. Therefore you are unable to say whether the water so discharged is or is not injurious to health, although it may pass off in a clear condition?—Clearness is not by any means a proof that the water is wholesome.

7081. Taking the sources of supply suggested to this Commission, either from Wales or from the lakes, as compared with the source of supply to the metropolis at this moment, to which would you give the preference?—Certainly, looking at the thing merely from a speculative point of view, one would prefer a water which had not received previous sewage contamination.

7082. Are you of opinion that water once contaminated with sewage can never be considered a safe water afterwards?—I think experience is quite against that. I think it is safe; evidence shows that it is safe in the majority of instances. There may be cases in which danger is produced.

7083. (*Sir B. Phillips.*) You have had no experience of any danger having arisen from the use of such water?—I am not myself practising as a medical man, therefore I can only speak from the reports of others upon that subject.

7084. Have you lived in London all your life?—I have lived in London for the last 30 years nearly.

7085. (*Chairman.*) Have you formed any idea as to the effect on the health of the present intermittent system, as compared with a constant supply, having regard to the means of storing water which, as you are aware, in the metropolis, especially amongst the poor, are very imperfect, namely, in ill-constructed vessels, the water remaining in a position in which it is absorbing gases from privies and other places, and having regard to the fact that a constant supply would get rid of that means of storing?—Looking at it entirely from an abstract point of view there can be no question that a constant supply is a much more wholesome method of supply than an intermittent one, on account of the manner in which the filth accumulates in those receptacles, so that although the water may have been delivered good originally, yet, from the mode of storage, it may have become contaminated or putrid.

7086. Would not a certain portion of the gases generated in a privy be absorbed in the water that is stored immediately contiguous to it?—They are liable to become so if the surface of the cistern is exposed, or if the waste pipe communicating with the drain is untrapped.

7087. Would soft water have greater power of absorption than hard?—That appears to be the case.

7088. (*Mr. Prestwich.*) Have you made any experiments upon the power of water, in a given course, to oxidise organic matter?—I ascertained a remarkable result in the course of the summer of 1859 upon the river. I took specimens of the water at Kingston, at Hammersmith, at Somerset House, at Greenwich, at Woolwich, and at Erith on the same day, and I examined the quantity of oxygen which the water contained at all those different points. I found that the quantity of oxygen at Kingston was the ordinary or normal proportion; at Somerset House it was much diminished; at Greenwich the whole of the oxygen had disappeared; at Woolwich it was much in the same condition, and at Erith the water was very much improved, showing that this diminution of oxygen had been produced by its action upon the water contaminated with the sewage of the London district, and that as it passed lower down the oxygen was again absorbed from the air, and again it became diluted with a large volume of water from below, from other sources, the Lea, the Ravensbourne, and other tributaries, and in this manner the water had again become oxidised. I look upon this as a direct proof of the effect of

W. A. Miller, Esq., M.D.

25 March 1868.

oxygen in destroying those organic contaminations which are thrown into the river?

7089. That is a case where the large addition of sewage which the river received as it passed through London, consumed all the oxygen which existed above London; but have you made the reverse experiments of the removal of organic matter by the action of oxygen?—Indirect experiments, but no direct ones—at least what I imagine is the result of oxidisation—but those experiments were brought before me; they were not experiments designed by myself. The chief experiment to which I refer was a particular mode in which water was filtered through an oxide of iron filter, which, I believe, acts as a conveyer of oxygen from the air to the water. That was in the case of the water supplied to Wakefield. The water was taken mainly from the river Calder, which flows past the town, and which is in a very filthy condition. At the time that I received it, it contained a considerable quantity of organic matter and a considerable quantity of sulphide of iron in a state of suspension, but it contained no oxygen. This water was pumped and filtered through a filter, one part of which consisted of oxide of iron, and the water as delivered in the town was one more free from organic matter than any river water which I have had an opportunity of examining, although previously it was very largely contaminated with sewage matter.

7090. Would that act for a length of time?—I have never myself had an opportunity of examining that filter, but there was an account of it given before the Commission on the Pollution of Rivers, in which it is stated that it has been in operation now for some years, and still appears to act, but it is necessary that it should be alternately exposed to the action of the air, so as to re-oxidize the iron, and again that it should allow the water to filter through it. The exposure to air, however, that is required appears to be not very long.

7091. You stated that there was no danger to be apprehended from the presence of peaty matter in waters from a soft water district; do you anticipate that there would be any indirect injurious effect produced upon the water by the removal during its flow from a distant source to London of any portion of air which the waters contained by oxidizing the peat?—If it is in an open culvert the exposure to air would, I should say, quite supply that which would be removed by the action of oxygen upon the peaty matter. If it was in a closed pipe it might be a question whether that would be so.

7092. Do you consider that the condition of water, as far as aeration goes, is a very important one for the supply of towns?—Yes, very much so. Generally speaking, a good deal may be judged from the proportion of oxygen. If the proportion of oxygen is much below the natural quantity, it is obvious that there must have been something at work to reduce it in the water itself.

7093. Do you anticipate that there would be any difference on that score with respect to soft or moderately hard waters; that is to say, if London were supplied with a water of a moderate degree of hardness, derived from sources near London, or if it were supplied with soft water brought from a distance, do you suppose that there would be any cause in operation to produce too low a degree of aeration in the soft water?—I do not anticipate that. I do not think that that would have any very material effect, but that is really a question upon which I can scarcely give an opinion which would be worth much.

7094. In looking for water for drinking purposes, what should you consider the essential or the more important conditions?—That it should be free from organic contamination to any marked extent, and clear and bright and cool, and not excessively hard

7095. Are not a very large proportion of the waters consumed in this country, or in any other country, flowing as they do over calcareous formations principally, hard waters?—Yes, they are.

7096. And the proportion of soft water used is comparatively small?—The Scotch waters are many of them very soft, and some of the waters in Cumberland are soft. Whitehaven and several large towns are supplied with soft water now, but in the south of the island the water supply is generally hard.

7097. Have you had occasion to notice whether the change from one water to the other produces any ill effects upon the health of the inhabitants?—I have no observations upon that point.

7098. You state that a certain proportion of nitrates is not injurious in water, and farther, you consider that it is not possible to say whether those nitrates are derived from previous sewage contamination or from original sources, such as springs, which are perfectly free from previous sewage contamination, as the nitrates are found in both descriptions of water?—Yes, that is the case.

7099. You consider, do you not, that in small quantities the presence of such nitrates would be innocuous?—Yes; the presence of large proportions of nitrates would no doubt indicate communication with some source of animal refuse. Well waters in towns very commonly contain large quantities of nitrates, especially in the neighbourhood of graveyards.

7100. But they contain very unusual quantities?—Yes, quite large quantities; sometimes I have seen as much as 20 grains in a gallon.

7101. Have you had occasion to analyse any waters which you have reason to believe are removed from the possibility of previous sewage contamination, and yet found nitrates present in them?—Yes, the waters from Watford, which come from chalk wells, where there can be no suspicion of previous sewage contamination, always contain nitrates.

7102. Have you had occasion to examine any springs or other sources of water supply?—I have examined a good many waters from various parts of the kingdom at different times, but the waters which I have had to examine, generally speaking, have been detached specimens of water which have been suspected of some injurious contamination, and they have been sent up in consequence of that circumstance. I have examined waters for the medical department of the Privy Council, and have done so for some years, and have had specimens from various parts of the kingdom where the water has been supposed to be injurious to health.

7103. You consider, then, that the presence of nitrates may be referred to various causes other than the existence of ordinary sewage in the water?—Yes.

7104. Organic nitrogen, I presume, is the substance the presence of which in any excessive quantity is to be avoided?—The presence of organic nitrogen may be derived from substances which are quite harmless, or it may be derived from substances which are very injurious, and we have no means of distinguishing between the two. Nitrogen is always present in such combination, not as nitrates, and not as ammonia; but the presence of nitrates is always a suspicious circumstance in water, and the greater the quantity of nitrates the more suspicious is the nature of the water and the more reluctant one would be to use such a water as a source of supply.

7105. Then are you of opinion that the mode of inquiry which has been adopted with regard to determining whether that organic nitrogen arises from animal matter or from vegetable matter fails to determine that point?—It fails to determine that point, but still, as I stated before, organic nitrogen is more often traceable to organic matter derived from animal refuse than it is to other sources; especially, for example, if a river which was known to pass through a thickly inhabited district furnished a quantity of this organic nitrogen there would be a strong suspicion that there was a quantity of undecomposed organic matter derived from animals in the stream.

7106. You have probably noticed the observations which have been made by Dr. Frankland with regard

to the suggestion which he throws out as to determining whether it can be referred to one cause or the other; do you consider that the experiments are conclusive?—I think Dr. Frankland has done more than anybody else to enable us to come to a conclusion upon that subject, but I do not think that his method at present is sufficiently tested to enable one to pronounce a very certain opinion upon it. It is a very laborious method, and I should doubt almost whether the results are adequate to the labour bestowed upon it. I have gone over with some considerable care his observations, and the method is an exceedingly ingenious one, and Dr. Frankland is a most accomplished analyst, but I agree very much with the objections which were stated by Sir Benjamin Brodie. I think the difficulties are at present that there has been no adequate verification, and that the errors of the analysis may possibly amount to as much as the substance which is to be determined. That is at present a matter under discussion. The subject is one of very great importance, and we are very much indebted to Dr. Frankland for the time and care which he has bestowed upon it, but I do not think he has settled the question as yet.

7107. Still the analyses being made by the same process would give results of the same comparative value?—Yes, they would give results of comparative value, especially in the same hands, and provided we knew what the probable error of the case was, but the probable error may amount to as much as the entire quantity which is to be determined. In some of those cases there can be no doubt that there is a very large proportion of organic nitrogen, but in cases where the quantity is small, the probable error evidently bears a much greater ratio to the amount which is observed.

7108. Can you point to any particular instance?—No, because we have not at present a sufficiently exhaustive investigation of the accuracy of the method. I think with Sir Benjamin Brodie that what is requisite is that this method, if it is at all to be relied upon, as a general method, should be most carefully and rigidly tried as to the errors of observation. Dr. Frankland has done something towards that in a paper, which he has just communicated to the Chemical Society, but I quite agree with Sir Benjamin Brodie that the proper plan is to take the same water and analyse it repeatedly, using different proportions of the water, and determining the quantities of organic matter by this method, say 30 or 40 times, so as to get the probable error.

7109. You have had occasion, no doubt, to examine the method adopted by Mr. Wanklyn?—Yes.

7110. Which method differs very materially, I believe, from that in general use?—Yes.

7111. Do you consider that there is sufficient definite value to be attached to the results obtained?—I am not able to give any opinion as to its quantitative value, but as a qualitative method I think it is of very considerable value.

7112. Do you think it a very important one for the detection of combined organic nitrogen?—Yes, it distinguishes very clearly between organic nitrogen and the nitrates, and I think that is one point in Dr. Frankland's method where further experiments seem to be needed, as distinguishing between the two.

7113. Do you not then consider this method of Mr. Wanklyn's applicable for exact analysis?—No, I do not think that at present it is made out that it is so. It appears to me that the experiments which have been made upon it both by Dr. Frankland and Mr. Wanklyn give results varying with the nature of the organic substance. Moreover, you never get the whole of the nitrogen from the organic substance, and I do not think you get a definite fraction of it. Mr. Wanklyn considers that he does, but I think that that is a point upon which he is in error.

7114. In any case you consider that it would be valuable in detecting the presence of that substance?—Yes, I think it is the best method for determining in a couple of hours whether a water is likely to be healthful or otherwise. If the water gives no organic nitrogen by Mr. Wanklyn's method, I think the probability is that the water is one which may be used. I think as a qualitative method it is an exceedingly useful one.

7115. Its value, therefore, is not so much in determining the amount of impurity, but in showing what waters are free from impurity and may be considered perfectly good waters for drinking purposes?—Yes.

7116. The method has not yet, I believe, had many months of trial?—That is so. Both those methods are at present under trial, and chemists have not yet had an opportunity of fairly testing either of them.

7117. Have you had occasion to notice the effects of soft water upon lead, and if so, what has been the conclusion at which you have arrived upon that point?—I have made a great many experiments upon that subject, and my opinion is that there is no doubt that perfectly pure water acts very rapidly upon lead. In the presence of atmospheric air and carbonic acid the action is extremely rapid, but if the water contains certain salts the action may be reduced to nothing whatever. For instance, the Loch Katrine waters act very rapidly upon both tarnished and untarnished lead in its ordinary condition. If you put a piece of lead into a bottle of Loch Katrine water and leave it exposed to the air it will gradually corrode the lead, and almost the whole of it will be converted into white lead, but that same Loch Katrine water, if it is sent through a pipe continuously, though it acts at first, will ultimately coat the inside of the pipe with a vegetable deposit which will entirely protect the pipe and there will be no action whatever upon the lead. The London waters now have always a trifling action upon lead, but it is so trifling that it is perfectly immaterial. The Loch Katrine waters, I believe, have absolutely no action after they have passed through the services for a certain time. They paint, as it were, the inside of the pipes and cisterns with a deposit of vegetable matter which combines with the oxide of lead, and so forms a closely adherent film which entirely prevents all change. I was certainly of opinion at one time that the Loch Katrine waters would be exceedingly dangerous to introduce into Glasgow, and I reported accordingly, but further examination has convinced me that that was a mistake.

7118. Have you had any opportunities of observing the same conditions in other towns supplied with soft water?—Yes, I have examined the soft water supply of several towns, at Manchester, at Whitehaven, and particularly at Inverness, and also at Perth and at Aberdeen. I visited all those towns especially with regard to the supply of soft water for the purpose of ascertaining the effect upon lead, and I did not find that there were any cases of lead poisoning which could be attributed to the use of soft water. At Whitehaven they had a hard water previously in the town, and a few years ago a very soft supply from Ennerdale Lake was introduced and there was no injury there. At first when the water was introduced they observed a few cases of injury traceable to the temporary action of the soft water upon the lead pipes, but they became shortly coated in the same way, and now I believe no case of lead poisoning is ever heard of excepting where a new lead service is put down.

7119. In your experience when visiting those various towns, had you occasion to observe the effect produced upon the health of the inhabitants by the introduction of soft water?—I made general inquiries, but I did not ascertain that there was any difference in that respect.

7120. (*Chairman.*) What time would be necessary for the formation of such a vegetable deposit upon a lead pipe as would prevent the action of the soft water upon the lead?—It depends very much upon the nature of the water, but with those peaty waters from the lakes it appears to take place pretty quickly, in a few weeks or perhaps less.

7121. (*Mr. Harrison.*) In the meanwhile, would the effect be injurious to health?—I made careful inquiries

W. A. Miller, Esq., M.D.

25 March 1868.

at that time, but I did not hear of any except half a dozen cases, perhaps, in Manchester, and one or two cases, perhaps, at Whitehaven, but still there was obviously nothing to be feared from that source of supply in its action upon the pipes generally.

7122. (*Mr. Prestwich.*) Supposing a district of chalk country were manured either by ordinary farm manure or by sewage matter, do you think it probable that rain water passing through a depth of 100, 200, or 300 feet of chalk should retain any traces of organic matter derived from any such source?—That is a question which is rather a speculative one. I should say not, but it is conceivable that fissures might occur in the chalk which would prevent the water from being thoroughly filtered, and in such a case it is possible that contamination of that kind might happen.

7123. In the absence of fissures, the tendency would be, I presume, to remove all impurities?—If it filtered through a body of chalk, it would be an exceedingly perfect mode of destroying them, because chalk is porous; it absorbs air freely, and the water is thus brought in a finely divided state into contact with the air under very favourable circumstances for oxidation. In fact chalk waters are proverbially brilliant, they are most beautiful waters when they issue from springs and perfectly colourless; if anything there is a slight bluish tinge when they are seen through a depth of 30 or 40 feet, but they are exceedingly beautiful and limpid.

7124. Have you formed any opinion yourself as to the comparative value of a supply of water of a moderate degree of hardness to a town, or of a soft water supply?—I should say that for drinking purposes a hard water is preferable, and it is liable to a less frequent change than a soft water. The principal objection which appears to me to arise in the case of soft water is that it is liable to peaty discoloration, which makes it at times very disagreeable for drinking purposes, and it is also more liable to absorb organic impurities, but as far as economical applications are concerned there is no doubt that there is economy in the use of soft water. I think that one of the principal objections to hard water is the manner in which deposits take place from it when it is used in boilers. There is always, in our chalk districts, a considerable deposit of hard adherent fur in the inside of boilers, kettles, kitchen ranges, and so on, which in time chokes the range and obstructs the passage of heat, and may occasion accidents. That seems to me to be one of the serious practical inconveniences from hard water which I do not think has been prominently touched upon.

7125. No inhabitant of London can be unacquainted with that inconvenience?—No doubt they are, and I suppose they feel the inconvenience to some extent. At the same time I should prefer, merely looking at it as an abstract question, water of a moderate degree of hardness for drinking. I must say that for domestic use soft water is preferable on account of its economy, but for dietetic purposes I think hard water has the preference.

7126. Do you know of any experiments bearing directly upon that question with regard to the effect upon health?—No, I have no observations upon that point. Having always lived in a hard water district I certainly prefer it for drinking purposes, but I believe persons who live in soft water districts are equally favourable to the use of soft water.

The witness withdrew.

Adjourned to to-morrow at 12 o'clock.

Thursday, 26th March 1868.

PRESENT:

SIR JOHN THWAITES IN THE CHAIR.

Alderman Sir BENJAMIN PHILLIPS.	THOMAS ELLIOTT HARRISON, Esq.
Colonel HARNESS, C.B.	JOSEPH PRESTWICH, Esq.

J. Simon, Esq.

26 March 1868.

JOHN SIMON, Esq., further examined.

7127. (*Chairman.*) You are desirous of adding somewhat to your former evidence, are you not, as to the qualities of the water supplied to the metropolis?—The point on which I thought it might be desirable for the Commission to have some some further information from me, relates to a question broached in my answer No. 2838. In that answer I speak of the great power of life and death which is exercised by water companies. I have at present a fresh and important illustration of the exercise of that power, not indeed technically by a water company, but by a Local Board practically acting as such; and feeling very strongly that the public requires more protection than it yet has against the occasional malfeasances of water companies, I propose to lay before the Commission this case which turned up in our office experience in the autumn of last year. The Commission, of course, knows that our office has to inquire into outbreaks of disease. Last autumn we had to inquire into an outbreak of typhoid fever at Guildford, and I believe the shortest account that I can give of what I wish to state to the Commission is contained in a passage of my now forthcoming annual report, and if you will allow me, I will read that passage. "The epidemic of typhoid fever at "Guildford was peculiarly instructive. Guildford is "not ordinarily quite exempt from typhoid fever, and "during the first 28 days of last August, 10 such "cases had been seen scattered about in the town, "when suddenly within the next 33 days there had "arisen fully 250 cases of the disease, and of this "large number 150 had arisen within a fortnight. "The distribution of the disease especially during "the first fortnight of the epidemic, so nearly corresponded in area with a particular section of the "public water supply of the town as to raise the "strongest suspicions that this section of the water "supply was at fault; and eventually these suspicions became a certainty. First, namely, it was "shown that on one particular day in August (about "10 days before the beginning of the outbreak), 330 "of the 1,675 houses of Guildford had exceptionally "received their water from a certain high service "reservoir which had been previously filled from a "new well, and that the persons residing in or "frequenting these 330 houses constituted the part "of the population on which the epidemic influence "had almost exclusively fallen. Subsequent chemical "examination of the water of the new well, detected "in it the products of organic decomposition, and "examination of the local circumstances showed, but "too unquestionably, whence the decomposing organic "matter had been derived. The new well, no one "could doubt, was most dangerously situated in the "porous and fissured chalk stratum; it was within "10 feet of various sewers; one of which, indeed, "was traversed as a short cut by the iron delivery "pipe of the high service; and when after the "epidemic this reckless confusion of sewer and water "works was dissected, the state of things found at

" the spot was reported to us in the following terms " by Mr. Taylor, one of the Poor Law Medical " Officers of the town: ' The engineers employed " ' in the repairs of the steam engine noticed " ' some exudation on the wall of the engine house " ' next the alley where the sewer runs, and the " ' pit of the flywheel contained a notable quantity " ' of the same. As the exudation had the smell of " ' sewage, the ground was opened in the alley " ' at a point adjacent to the engine house. " ' The sewer was found leaking in various places, " ' and the soil between it and the wall of the engine " ' house was saturated with sewage, of which as much " ' appeared to run outside as inside the sewer. This " ' was found to be an old fashioned 12-inch drain con- " ' structed with red unglazed gutter tiles with butt " ' joints and common mortar. The tiles forming the " ' lower half of the cylinder were in places completely " ' worn away, and at one point several feet of them " ' were missing, and the upper tiles had fallen in upon " ' the soil below. All the joints gave exit to water, " ' and the ground was a quagmire of filth beneath and " ' on each side. Dark coloured fetid slush had to be " ' dug out and removed in baskets, making the men " ' vomit who were employed in the work.' " There finishes the quotation, and then I go on, " There, of " course, could not be any reasonable doubt but that " the passage of this filth into the well, from which " the high service reservoir was filled, had been the " cause of the epidemic. Mr. Taylor further informed " us that the whole number of deaths from fever up " to the end of the epidemic was 21, including three " or four who died in other districts after removal " from Guildford, and that he roughly computed the " total number of cases of fever from August to " December at 500."

7128. (*Sir B. Phillips.*) What is the population of Guildford?—About 8,000, I believe, but my point is that this partial outbreak of fever was caused by the water.

7129. (*Mr. Harrison.*) That water was taken from the chalk?—Yes.

7130. (*Chairman.*) But the mischief did not arise from the fact that the water was taken from the chalk but from its subsequent contamination?—Yes, from contamination at the point where the well was sunk.

7131. (*Col. Harness.*) Have you any analysis of the water as it was supplied to the population?—Yes, I have an analysis, but I am not sure that in cases of this sort much importance must be attached to the chemical analysis. The best of all analyses in such cases is the analysis of the effect produced.

7132. Its value is as a comparison?—I have an analysis, which accompanied Dr. Buchanan's report, made by Professor Miller.

7133. Is that an analysis in which you have confidence?—Perfect confidence.

7134. Will you put it in?—Yes. (*The same was delivered in, and is as follows.*)

Analysis of Guildford Water.

Four samples of water were received duly stoppered in glass bottles, and labelled as follows:—

1. Old Well, Guildford, September 26, 1867.
2. New Well, Guildford, September 26, 1867.
3. Mill Tail, Guildford, September 26, 1867.
4. Guildford New Reservoir, October 1.

In the first three samples there was an extremely scanty reddish sediment; the fourth sample was quite bright. No sensible colour, smell, or taste was exhibited in any of the samples, except that from the mill tail, which had a faint yellowish tinge and a slightly musty taste. They are chalk waters, and soften considerably on boiling; and like most chalk springs, seem to soften by exposure to the air. That from the reservoir, where it had been standing for two months, as Dr. Buchanan informs us, is considerably softer than that taken newly from the well.

There is nothing remarkable in the amount or quality of the saline matter, a little ammonia, and a small amount of nitrates are present: the ammonia derived probably from surfaced rainage, it is distinctly more in the new well water than in the old. The amount of nitrates is small in all cases. So also is the quantity of organic matter, which, however, is decidedly greater in the new than in the old well. After standing in the reservoir for some weeks, it appears, as is usual in such cases, to have undergone a partial oxidation, the quantity of nitrates having increased, whilst that of the ammonia and organic matter has distinctly diminished.

The aëration of the water from the old well is perfect, *that from the new well very defective.* But this water after it has stood in the reservoir (specimen No. 4), has nearly recovered its proper proportion of oxygen. The water from the new well, No. 2, appears to have contained some putrescible or rapidly alterable substance, which has absorbed a large quantity of the dissolved oxygen which spring water ought to contain.

I subjoin details of the analyses:—

Guildford Waters.	1 Old Well.	2 New Well.	3 Mill Tail.	4 New Reservoir.
Appearance	Nearly bright	Nearly bright	Nearly bright	Bright
Colour	—	—	Slight yellowish	—
Taste and Smell	None	None	Slight musty	None
Clark's Scale. Hardness before boiling.	15°·1	16°·2	8°·7	10°·7
Clark's Scale. Do. after boiling one hour.	4°·8	4°·1	3°·9	2°·9
Total solids in grs. per gall.	23·2	24·0	13·4	21·8
Fixed salts	22·7	23·2	12·5	21·4
Volatile and combustible matters.	0·5	0·8	0·9	0·4
Nitric acid, N_2O_5	1·20	1·10	0·20	2·05
Ammonia	0·01	0·02	0·01	0·007
Gas in cubic inches, per gallon.	16·30	19·49	15·22	16·30
Carbonic acid, CO_2	7·74	8·18	4·11	6·19
Oxygen	2·85	1·17	2·89	2·93
Nitrogen	5·71	10·14	8·22	7·18
Ratio of oxygen to nitrogen.	1 : 2·05	1 : 8·6	1 : 2·84	1 : 2·4

7135. (*Chairman.*) I think when you were examined before, you were asked your opinion as to the effect of sewage contamination in rivers, and after how long a period, and at what distance of flow, the river would get rid, if at all, of that sewage contamination; have you formed any opinion upon that point?—I cannot venture to answer that question with any confidence; it is a very difficult question to answer.

7136. But are you of opinion that the water of a river which had been under the influence of such contamination would ever after be a safe water for domestic purposes?—The answer to the question, if it is to be absolutely correct, must vary with the quantity of sewage, the volume of water, and the distance between the point of contamination and the point to which the question applies.

7137. Supposing that sewage is discharged from one of the sewers, say at Windsor, would it be possible to detect the presence of that sewage seven miles lower down the river, having regard to the volume of water in the river?—I believe it would be absolutely impossible for chemists to discover it, but the practical sanitary question is different. Supposing tape worm eggs to be sent into the river with that sewage, would those tape worm eggs be alive seven miles down? Or, supposing cholera discharges to be sent into the river, or the discharges of typhoid fever, and assuming (which is a frequent pathological opinion) that the respective contagia of typhoid fever and cholera are living germs, would those germs be alive seven miles down. It is not a question whether a chemist would find out the organic matter so much as it is a question whether those particular molocules would still have their property seven miles down. I cannot say that they would not.

7138. Could you detect them at that distance?—Only by their effects.

7139. (*Sir B. Phillips.*) Might not the same disease be produced from any other cause?—The particular parasite will only come from its particular egg. You would not get hydatids except from eggs any more than you would get chickens without eggs.

7140. Are the Commission to understand you to state that it is impossible for a chemist to discover the existence of sewage at the distance named?—The possibility varies with the conditions I have stated.

7141. If it is not possible for a chemist to discover

J. Simon, Esq.
26 March 1868.

it, is it not presumptive evidence either that it does not exist, or that if it does exist it is in such minute quantities that it is in no way deleterious to human health?—I am very decidedly of opinion that that principle is not a safe one to adopt as a basis for sanitary regulations in the matter. I think the rule ought to be that no sewage should go into any water that can be used for drinking purposes. I think, even, that allowance should be made for the proper decent taste of people. Water into which sewage has been discharged is, in relation to the matter now under consideration, an experiment on the health of the population, and I do not think that that experiment ought to be tried. Moreover, as a mere matter of taste, people would rather not drink water into which sewage has been discharged, and I think that that in itself deserves consideration.

7142. (*Chairman.*) Supposing that the inhabitants of the metropolis were generally speaking in a robust and healthy condition, although they were drinking water from the Thames which had been polluted by sewage with impunity for a given period, and that the condition of the atmosphere suddenly changed and there was a general depression of the resistive force of the human system, would not the drinking of that water have a tendency to develope disease more rapidly than if they were taking water free from the objection to which you refer?—I think the drinking of such water is dangerous. It is not practicable to define the exact line at which the danger in a particular case begins. Everybody knows that water with certain obvious pollutions by sewage is fatal to health, and I do not know where to draw the line in practice between such cases and those which are practically speaking unimportant. The question whether at the sources of the Thames a particular watercloset empties into the river, may be in itself entirely unimportant to Londoners, but I cannot draw my line between that case and cases where the danger would be unquestionable; and I venture to maintain that the principle ought to be that there should be no sewage discharged into running water.

7143. Then the effect is so doubtful in your mind, that the safer course having regard to the possibility of obtaining a supply from other sources would be that water once contaminated with sewage should not be used for drinking purposes?—Yes. I would rather, however, state it in the other form, that the sewage should not be allowed to go into the water. For what can we do in London? It is all very well to say that water contaminated with sewage is unfit for drinking, and that we ought not to drink it, but when towns up the river are still draining into the Thames what can we do? We have no choice.

7144. If the Thames is freed from all discharge of sewage into it, it is quite clear, is it not, that that objection would not arise?—Quite so.

7145. And your doubt would be at an end?—Yes.

7146. Have you analysed the water from Croydon?—Not in our office.

7147. Can you give an opinion as to the condition of the water at Croydon, when it passes off?—I am not prepared to say that at present. The point with respect to which I was particularly anxious to speak was the want of public protection against such injuries as those which have been inflicted at Guildford. There, no doubt, the injury was on a small scale, but in other cases it might be on a very large scale.

7148. That is rather a question as to the *modus operandi* in the distribution of the water; it is not a question as to the source and quality of the water?—No.

The witness withdrew.

R. Hassard, Esq.

RICHARD HASSARD, Esq., further examined.

7149. (*Chairman.*) You are desirous are you not, of making some further statement, with regard to the evidence given by Mr. Bateman, in reference to the cost of your plan as compared with his?—Yes.

7150. (*Mr. Harrison.*) In the evidence which you gave on the 19th of March, you put in a table which showed the area of the drainage into Loch Katrine, and the area of Loch Katrine itself; you gave also, did you not, a similar calculation as to the area of the two divisions of Mr. Bateman's Welsh scheme?—Yes.

7151. I do not know whether you recollect my referring on a previous occasion to Bala Lake, as bearing upon that point?—No, I was not present upon that occasion.

7152. Could you give the Commission the proportion of the drainage area to the Bala Lake as compared with its surface?—Bala Lake has a surface of 1,100 acres, and the area draining towards it is 35,400 acres.

7153. Am I correct in the calculation which I have made from the previous evidence, that with regard to your Cumberland scheme, the total area of drainage is about 113,000 acres, and the water surface of the lakes 4,639 acres, or in the proportion of 1 to 25?—Yes, or thereabouts.

7154. In the case of Bala Lake, I make it to be 1 to 33, is that correct?—Nearly so, it is 1 in 32.

7155. Assuming that I am right in that comparison, that Bala Lake is 1 to 32, and your own Cumberland lake scheme is 1 to 25, a comparison has been made with Loch Katrine, which is 1 to 7?—Yes.

7156. And because the Welsh lake scheme is in the one case 1 to 25, and in the other 1 to 29, you draw the argument from that, that the exposed surface, is not sufficient to clear the water, what distinction do you draw between the Bala Lake, or the Cumberland lakes and the Welsh scheme, with respect to that?—As regards the southern portion of the Welsh scheme, I draw this distinction, that there all the waters both pure and turbid must be empounded in we same reservoir. In the lake district it is different, he there contemplate a larger area of pure reservoir as compared with their storage and their drainage. We contemplate a separation, turning the turbid water into the compensation reservoirs and using that for compensating purposes, and using the pure water only for town use.*

* The witness subsequently sent in the following additional remarks on this subject:—"I also draw this very important distinction, that as regards the Welsh scheme there is no portion of the gathering ground, except that draining into the proposed Llanwddyn reservoir, similar, as regards the clean nature of the district, and as regards freedom from cultivation, to the watershed of Bala Lake; that Bala Lake is nearly four miles in length, and that all or almost all its tributaries enter it at or near the upper end, thus giving a long period of time for the water to clear itself by subsidence and exposure. That as regards the Welsh, scheme, the very converse would be the case, as in three out of four of the proposed main reservoirs, viz., in the two reservoirs on the River Banw and in the Trefeglys Reservoir, the principal tributaries and those which would bring in the foulest water would deliver into the reservoirs near their lower or at their lowest ends, immediately adjoining the points at which the water would be drawn off for use, and that under such circumstances the dirty water would necessarily be drawn off from the reservoirs almost immediately after entering them, and the period of time available for clarification by subsidence and exposure would be extremely short, and I have stated and maintain that under these circumstances filtration could not be dispensed with, as is found to be the case at Liverpool, Dublin, and other large waterworks, where all the water, both pure and foul, is impounded in the same reservoirs, although in the cases just mentioned the main tributaries all enter at or near the upper ends of the reservoirs, and the water has consequently the utmost advantage to be obtained from lengthened exposure. In the case of Liverpool the area of water surface is to the drainage area as 1 to 21, and in the case of Dublin as 1 to 32, the last being in precisely the same ratio as at Bala Lake. In the Lake project, matters are entirely different. The drainage area is there so clean and devoid of cultivation, that only two or three of the streams (those in the lower part of the district) ever are coloured or turbid, and provision is there made for turning them, when swollen or foul, into compensation reservoirs for millowners' use, and for impounding the pure water in separate reservoirs, and using it only for town supply."

7157. (*Chairman.*) Would not that apply to the Welsh scheme also?—Certainly not; the circumstances are entirely different.

7158. (*Mr. Harrison.*) Still the comparison which you drew, the details which you give in explanation of it now, was that Loch Katrine being 1 to 7, and the Welsh scheme 1 to 25 in the one case and 1 to 29 in the other, there was not sufficient exposed area of water surface?—If you recollect, I raised my objection before that, as to the same reservoirs being used for both purposes, and I then stated that the comparison of those reservoirs with Loch Katrine was not made under similar circumstances.

7159. Do you think you are quite right in the statement that Mr. Bateman, in estimating the cost of constructing his reservoirs in the Welsh district, which is 1,060,000*l.*, has only taken in the northern portion of his scheme?—I take Mr. Bateman's own statement in his evidence of the 11th of March in answer to question 6703, where he says, "My estimate of the cost of "constructing the reservoirs which I have laid out, "and collecting all the water, upon very carefully "considered plans is 1,060,000*l.* That includes all "the flood-water courses, and the reservoirs, and all "means of collecting and storing."

7160. Taking that to be the answer, will you point out in Mr. Bateman's detail where it is that he has made that out. You say that you get it out to be 2,200,000*l.*, will you refer me to those figures?—When I gave this evidence, if you recollect, I had not gone into Mr. Bateman's detail, and I requested permission to go into it at a future day, as his evidence had been handed to me only the evening before, and therefore I had not had time to examine the estimates until the interval which has elapsed between that day and this day. In his evidence the estimate is given at question 6567, where you will find that the estimate for the northern portion is 1,089,019*l.*

7161. That includes the branch aqueduct; it is 489,882*l.* for the reservoir?—The 2,200,000*l.* which I stated that day was stated from a sum given in round numbers in Mr. Bateman's pamphlet.

7162. In his estimate the figure for the reservoirs in the first instalment is 489,882*l.*, and in the next page 570,291*l.* for the other reservoirs, which make 1,060,000*l.* as he gave it?—I included the two branch aqueducts to the Marten Mere, up to the commencement of the main aqueduct.

7163. That is not what Mr. Bateman has taken?—I take it as 2,200,000*l.* to the junction of the branch aqueducts, that is to say, at the commencement of the main aqueduct.

7164. Then you are taking a different point from what Mr. Bateman takes in his evidence?—I compared it with the similar cost of working, collection, and impounding in our estimate, that is to say, all the works that are necessary up to the commencement of the main aqueduct. I have put it in the wrong place, that is all.

7165. You have taken the two branch aqueducts, therefore Mr. Bateman's figures so far are perfectly correct?—I understood Mr. Bateman to refer to works which were necessary both for impounding and for conveying the water to the commencement of the main aqueduct.

7166. He has taken it from the point of discharge from the reservoir?—I presume that that must be the case.

7167. If you look at page 8 you will find for reservoirs and works, for collecting and storing water in the Vyrnway and Banw district, including land and contingencies, 489,882*l.*; then if you take the next page you will find this: "Second instalment of 40,000,000 "gallons additional. Reservoirs and works for collecting and storing water in the River Severn "proper district, including land and contingencies, "570,291*l.*," those are the two figures which make the 1,060,000*l.* given in the estimate?—Yes, but I take the branch aqueducts in.

7168. (*Chairman.*) Have you had an opportunity of examining Mr. Bateman's evidence, wherein he draws a contrast between your scheme and his own, and especially with regard to the cost of each?—Yes.

7169. Are you desirous of making any statement with regard to that?—Yes. I entirely object to the prices at which Mr. Bateman has estimated the cost of our project; they are very different indeed from the prices at which the Welsh project has been estimated; in some cases they amount to as much as 50 per cent. additional. I propose going into them *seriatim*, in the same way as Mr. Bateman has done. I will take, first, the relative cost of constructing the reservoirs in the two districts, and the prices at which they have been estimated. I find, by referring to our own estimates, that for the reservoirs, embankments, including puddling, pitching, and soiling the slopes, we have allowed the amount of 2*s.* per cubic yard. In Mr. Bateman's project the prices are 1*s.* 6*d.* and 1*s.* 2*d.* In one case only, viz., that of the Nant-y-Eira reservoir, which is a small one, has Mr. Bateman taken 2*s.* per cubic yard to cover these portions of his works. And as regards the cost of eduction tunnels, pipes, and valves for drawing off water from the reservoirs, in our proposed Haweswater and Thirlmere reservoirs we have taken the cost of these as 19,000*l.* and 25,000*l.* respectively, averaging 22,000*l.* for each reservoir; whilst the price that Mr. Bateman has allowed for the similar works in his scheme averages for each reservoir only 11,414*l.*, although for four out of his seven proposed reservoirs the works in the Welsh project must be quite as costly as in ours. Next, as to the cost of the land and property required for the reservoirs, conduits, and works of collection, in our estimates of the cost of the poor mountain land which would be required adjacent to Haweswater and Thirlmere Lakes, we have taken its value at 75*l.* per acre; and for the narrow stripe on the shore of Ulleswater, for the purpose of here and there constructing a new road, we have allowed 80*l.* per acre, and in addition to that we have made liberal estimates for such house property as we should require. In estimating the cost of that portion of the first section of our works from Ulleswater to the Kirkstone tunnel, the land required for which is of poor rocky quality, Mr. Bateman, in his evidence appended to his reply to question 6713, assumes its value at 100*l.* an acre. The quantity of land required is a little overstated, but that is not a matter of any very great moment. I have taken out very carefully the quantities of land which would be required for each branch of Mr. Bateman's project; and taking the areas of the reservoirs as given, and taking the width of one chain round the water's edge, to allow for beaching, fencing, and diverted roads round the reservoirs, and taking the width of the land occupied by the various flood-water courses, and by the aqueducts from the reservoirs to Marten Mere, as averaging one chain in width, I make the total quantity required for the northern section of the scheme to be 3,124 acres, and for the southern section 2,622 acres—that is, including the two branches to Marten Mere. Mr. Bateman's estimate of the cost of land required for the northern section of his project, including rebuilding a village, a church, and compensation, is 180,240*l.*, being at the rate of about 58*l.* per acre, inclusive of house property. If we deduct from the total amount of 180,240*l.* the value of the house property, estimated at the same scale which we adopt in the Lake project, that amounts to 45,100*l.*, and that will leave him available for land and compensation 135,140*l.*, or about 43*l.* per acre only, as against our 75*l.*, and as against 100*l.* at which he estimates it for us. The cost of the land for the southern portion of the Welsh scheme is taken by Mr. Bateman as 199,550*l.*, being at the rate of about 76*l.* per acre, inclusive of house property. But if we deduct from that the value of house property as above, amounting to 43,150*l.*, that will leave him available for land and compensation 156,400*l.*, or about 59*l.* per acre only. Therefore the prices that we have taken are 75*l.* and

R. Hassard, Esq.

26 March 1868.

80*l.* per acre, as against 43*l.* and 59*l.* per acre assumed in the Welsh project. We have for the earthworks 2*s.* per cubic yard, as against 1*s.* 6*d.* and 1*s.* 2*d.*, and for the eduction apparatus, tunnels, and waste weir at each reservoir we have an average of 22,000*l.*, as against 11,414*l.* in the Welsh project.

7170. Have you worked it out into a balance sheet? —Yes (*delivering in the same*).

TABLE shewing the Prices for Property and Works as adopted by Mr. Bateman in his Estimate for the Welsh Scheme, compared with the Prices for similar Matters and Works which he has adopted in his Estimate for the Lake Project.

—	Land for Reservoirs and Works of Collection, after deducting Value of House Property, per Statute Acre.	Earthworks in Reservoir Embankments, including puddling, pitching, and soiling Slopes, per Cube Yard.	Eduction Tunnel, Pipes, Valves, and other Apparatus, Average for each Reservoir.	Tunnel through Clay Slate Rock, Area 240 Square Feet, per Mile.	Tunnel and covered Conduit on Line of Main Aqueduct, per Mile.	Open Conduit on Line of Main Aqueduct, per Mile.	Syphons of Wrought-iron Pipes, on Line of Main Acqueduct, per Mile.	Observations.
			£	£	£	£	£	
Prices adopted by Mr. Bateman in estimating for the Welsh Scheme.	43*l.* to 59*l.*	1*s.* 2*d.* to 1*s.* 6*d.* in one case only, and that for a small Reservoir, 2*s.*	11,414	38,720	33,180	25,000	No wrought-iron Syphons.	
Prices adopted by Mr. Bateman in estimating for the Lake Project.	100*l.*	—*	—*	88,000	50,000	35,000	127,000	* Mr. Bateman gives no detail, but states he adopts Messrs. Hemans and Hassard's prices, although the prices at which he would have estimated these works would have been higher.

7171. (*Mr. Harrison.*) Have you any idea what the rent per acre is of the land in the Welsh district? —I have not. It is the best land in that country; the whole population is crowded into the valleys: it is the most fertile land in the country.

7172. (*Chairman.*) It is in a civilised district, because Mr. Bateman removes a church?—Yes, he removes two churches and four or five chapels. The next objection I have to raise is as to the price at which Mr. Bateman has estimated our Kirkstone tunnel. It is a long tunnel, six miles in length, out of which $4\frac{1}{4}$ miles is an ordinary shallow tunnel, and $1\frac{3}{4}$ mile is what I may term a heavy tunnel; it is in the central part of the pass, between the two working faces, where shafts could not be put The whole of that tunnel is estimated by Mr. Bateman at 88,000*l.* per mile, or 50*l.* per yard.

7173. Is it through limestone?—It is clay slate, silurian. For the central portion of the tunnel I do not think that his estimate is very much out; in fact, we have allowed 80,000*l.* ourselves for the centre portion, so that the difference is not very great between us; but I find that in the Welsh scheme, if you refer to the estimates appended to Mr. Bateman's reply to question 6567, he has taken the cost of a tunnel to carry off 120,000 cubic feet of water per minute at 22*l.* per yard, or 38,720*l.* per mile. If the water were passed through that tunnel at the enormous velocity of 500 feet per minute, or $8\frac{1}{4}$ feet per second, it would require a tunnel of 240 square feet in area, being precisely the same dimensions as that which Mr. Bateman has estimated for our Kirkstone pass tunnel. As the Welsh tunnel is through clay slate, in every respect similar to the greater portion of the Kirkstone pass tunnel, it is evident that the two ought to be estimated at the same rate of price, whereas I find in the Welsh scheme a tunnel which must have an area of 240 square feet, is estimated at 22*l.* per yard, or 38,720*l.* per mile, while for the same class and size of tunnel in Cumberland it is estimated at 88,000*l.* per mile.

7174. Is Mr. Bateman able to get more faces than you can in Kirkstone pass?—A certain portion of Kirkstone pass must be worked, of course, from two faces only, but in the remaining $4\frac{1}{4}$ miles we can get any number of shafts down that we please. I do not object to the 88,000*l.* for the central portion of the tunnel, but I object entirely to his estimate for the remainder.

7175. Can you give a short summary, showing what the difference would be?—Yes, I have handed it in. The next objection I have is as regards the covered and open aqueduct in the second division of our project, from Ambleside to Stockport. In estimating for that portion of the work Mr. Bateman takes its cost, if you refer to the estimate appended to his reply to question 6713, at 50,000*l.* per mile for the covered aqueduct and tunnel, and 35,000*l.* per mile for the open aqueduct, whilst in his own project, where he contemplates using more expensive material and a more expensive class of workmanship, he estimates the cost, if you refer to the estimate appended to his reply to question 6567, at 33,180*l.* per mile and 25,000*l.* per mile respectively. So that in our district, where we have abundant building material of every kind, and where we do not contemplate the same costly class of work as in the Welsh project, considering it unnecessary, it is estimated for us at 50,000*l.* and 35,000*l.* per mile respectively, whilst in the Welsh project the same work is put at 33,180*l.* and 25,000*l.* The facts of the case however are, that for that portion of the work, for tunnel, covered conduit and aqueduct on substructure, which is as nearly as possible the same price as the tunnelling, our estimate averages 37,360*l.* per mile, that is about 4,000*l.* more more than Mr. Bateman has adopted in his own project, as against 33,180*l.* per mile for the Welsh scheme. The open portion of the aqueduct we have estimated at 20,000*l.* per mile, which is less than what Mr. Bateman has estimated his own project at. As regards the second portion, from Macclesfield to Edgware, the works of our project, where we also contemplate a less costly class of work than that projected for the Welsh scheme, are estimated at 50,000*l.* per mile, as against 33,180*l.* for the Welsh project (that is covered aqueduct). We have estimated that portion of our work at 32,280*l.* per mile, which is very nearly the same a mount as Mr. Bateman has estimated for the same description of work in the Welsh project. For the open portion of our aqueduct we have taken 21,000*l.* per mile, and it is estimated for us by Mr. Bateman at 35,000*l.* The estimate for similar work in the Welsh scheme is 25,000*l.* per mile. The remaining objection which I have, is as to the cost at which the proposed wrought iron syphons are estimated. The pressure under which the pipes will work and the weight of the pipes I make considerably less than Mr. Bateman has done, there is a very small proportion of the total length of the pipes which will be under a pressure greater than 200 feet, and the average pressure will be somewhere about 150 feet, and the average weight per yard of the pipes will not be more than 19 cwt. We have estimated these pipes at the rate of 33,000*l.* per mile of

R. Hassard, Esq.
26 March 1868.

single pipe, which is equal to 18*l.* 15*s.* per lineal yard, and the way in which that estimate was as made up was as follows. Wrought iron, 19 cwt. at 16*s.* per cwt., that amounts to 15*l.* 4*s.* Rendering of the internal surface of the pipe with Portland cement, eight square yards at 2*s.* 3*d.*, that is 18*s.* Excavation and refilling 16 yards at 1*s.* 6*d.* that is 1*l.* 4*s.*, and the lead and labour at the joints 13*s.*, making 17*l.* 19*s.* Then the way-leave, at six acres per mile for temporary damage, at 50*l.* per acre, amounts to about 3*s.* 6*d.* per lineal yard; that makes a total of 18*l.* 2*s.* 6*d.* Then I add to that for contingencies 12*s.* 6*d.*, making 18*l.* 15*s.* altogether per yard forward. I have not any further observations to make upon the estimates, but I may mention that since I was last examined I took an opportunity of ascertaining the height of the Maiden Lane reservoir of the New River Company, and it is, as Mr. Bateman stated, 231 feet 6 inches above Ordnance datum.

7176. Then you would be unable to deliver into that reservoir?—That reservoir would require to be altered.

7177. What height?—It would require to be altered probably 20 feet, and the upper tier, if I may so term it, of houses that were served by that reservoir, would have to be put in connexion with the reservoir immediately above.

7178. Would the water have to be lifted by a stand pipe?—No, there are several reservoirs at higher levels than that belonging to the New River Company, and it could be done merely by the transfer of a few of those houses from the service of that reservoir to that of the one next immediately above it.

7179. Then do you still adhere to your previous estimate?—Certainly. I may mention that if there is any doubt, or any question raised as to the sufficiency of the fall of our aqueduct, and the height at which we propose to deliver in London, there is another mode of collecting and drawing off the water from the lake district, which would obviate all those objections, without any additional cost whatever.

7180. Would the form of your culvert resist any greater fall than you have given to it?—We propose to work at a velocity varying between 106 feet per minute and 128 feet per minute. A greater velocity than 128 feet per minute in an aqueduct of that kind I should not venture upon under any circumstances. In the open aqueduct, where the culvert has a fall of only 4 inches per mile, the velocity varies from 106 to 109 feet per minute, and where it has a fall of 6 inches per mile it is from 127 to 128 feet.

7181. Mr. Bateman's velocity is much greater than yours?—Yes, in one portion of the works, in the covered aqueduct.

7182. Would it be necessary for Mr. Bateman to increase the cost of that portion of his work?—I would rather Mr. Bateman answered that question himself. I should not venture to work at such a velocity in a covered aqueduct of that nature; 170 feet per minute, I think, was the velocity that he gave.

The witness withdrew.

Adjourned to Thursday next, at 12 o'clock.

Thursday, 2nd April 1868.

PRESENT:

SIR JOHN THWAITES IN THE CHAIR.

Alderman Sir BENJAMIN PHILLIPS.	THOMAS ELLIOT HARRISON, Esq.
Colonel HARNESS.	JOSEPH PRESTWICH, Esq.

Dr. ROBERT ANGUS SMITH examined.

Dr. R. A. Smith.
2 April 1868.

7183. (*Chairman.*) What office do you hold?—I am inspector of alkali works for the Government, under the Board of Trade.

7184. Have you directed your attention to the quality of waters supplied for domestic purposes?—Yes, I have.

7185. Have you made any analyses which you can refer to as giving information on that point?—I have made a great many analyses, but I have not brought any with me. I only intended to speak here on general principles, and especially about the organic matter which seems to have raised a discussion of more importance than, I think, any other subject in connexion with water.

7186. Will you be good enough to state your views upon the subject?—Some time ago, in studying the organic matter of water, I divided it into many parts. It had been common in analyses of water to write down the organic matter as if it had some special quality. Afterwards, however, I found it necessary to consider organic matter as a very complex substance, and instead of putting it down under one head I have put it down under at least eight heads, and some of those heads have subdivisions. The first head which I think it would be worth attending to is organic matter, which is putrefied. This would include the gases and vapours arising from putrefaction, and this is the thing which strikes one more especially on coming in contact with water which is impure; for example, in drinking it would be offensive to the smell, and generally it will give those characteristics that were found in the Thames some two or three years ago. I examine this part by means of permanganate of potash. It is very readily done.

7187. As I understand it, although you break up that which is usually designated organic matter into eight parts, still those eight parts form but one matter that is called organic?—It is so; it is one of the great divisions.

7188. None of those eight parts would have reference to anything except the original matter which is called usually by chemists organic matter?—No; but they will be as different in their properties as, I may say, organic or inorganic matter are—so widely apart are they in quality. It is difficult for one to give exactly all the particulars, but I will first say how I examine the gases of putrefaction. I use generally permanganate of potash for that purpose; that was the plan adopted by Professor Vorckhammer, of Copenhagen, some years ago, for organic matter generally, and it has been adopted by several chemists since, and rejected by several others as of no value. I find that it is of value for some points, but it is of no value in ascertaining the whole organic matter. I have rejected it therefore for the whole organic matter, but have adopted it for the putrescent organic matter. As many opinions have been given concerning this process, I may say that I cannot wholly agree with any party. I do not know how to use it so as to ascertain the whole organic matter, but I will not say that it cannot be used so. I say, however, that the putrid matters which I estimate so as to obtain comparative amounts by the permanganate are not estimated at all by any other mode known to me, and chemists as a rule reject them entirely. They boil them away, and disregard the most dangerous and

Dr. R. A. Smith.

2 April 1868.

the most offensive substances next to germs of disease seeking to reach bodies which are doing no harm at the time, and may or may not do harm afterwards according to circumstances. In other words, the non-putrid nitrogenous matter is considered of more importance than the putrid. This may be when the water is not to be used at once, but to be stored, and when we know that the non-putrid matter in it will become either putrid or living. The permanganate results are almost entirely in agreement with those of the senses, but they are more refined. Any chemist who neglects to ascertain if nitrites, iron, and such substances are present affecting the permanganate, must bear the consequence of his negligence. I find that by examining sewage water in this manner one arrives at results which I think are of importance. As an example of that I may give a short description of an examination of the waters of the Clyde which I made in the year 1866. My object was to trace the sewage water down the Clyde from Glasgow into the ocean. I therefore took specimens at different places from 6½ miles above Glasgow almost to Liverpool, and I obtained results which I think are interesting, and also valuable. At the place where I began, which was 6½ miles above Glasgow, it appears that the oxygen per 100 gallons required to oxidise the decomposed matter was 3·15; at 5½ miles above Glasgow it had increased to 4·55, further down to 5·95, then to 15·40, and so on.

7889. Are there any sources of contamination above the point where you took the water at 6½ miles above Glasgow?—Yes, there is the small town of Hamilton, and the town of Bothwell.

7190. Do those towns drain into the river?—Yes. I may say that there are also substances in the water which originally would have affected the test; that is to say, there is peaty matter which would affect it, and that is also to be taken into consideration. However, the quantity rose up to 15·40, then 11·55, and then 10·85; then about 12 miles down it had gone to 4·55, and 18 miles down it had come to the position in which it was 6½ miles above Glasgow, that is to say, it requires 18 miles to make that progress; afterwards, where it began to go into the Frith of Clyde or the sea, it fell down to ·70, and at last I may say that ·35 was about the point at which it stayed in the ocean. I will hand in a table of those observations.

The witness delivered in the following table:—

—	Time.	Oxygen per 100 Gallons required to oxidise the decomposed Organic Matter.
	Augt. 15th, 1866.	
6½ miles above Glasgow	3.30 p.m.	3·15
5½ miles above Glasgow	3.15 p.m.	4·55
5 miles above Glasgow—Cambuslang	3.0 p.m.	5·95
Broomielaw	1.30 p.m.	15·40
Mouth of Kelvin	1.20 p.m.	11·55
100 yards below Renfrew	1.0 p.m.	10·85
100 yards above Bowling	12.45 p m.	4·55
At Dumbarton	12.30 p.m.	4·55
Between Greenock and Port Glasgow	12.10 p.m.	3·15
	July 25th, 1866.	
Gourock	12.55 p.m.	1·05
Cloch	12¾ p.m.	1·05
Inverkip	12½ p.m.	0·70
Wemyss Bay	12¼ p.m.	0·35
Opposite Toward	12 noon	0·70
Between Toward and Cumbræ	11½ a.m.	0·70
Opposite Cumbræ Lighthouse	11.0 a.m.	0·70
Opposite Lamlash	10¼ a.m.	0·35
188 miles from Liverpool	10.0 a.m.	0·35
176 „ Ailsa Craig	9.0 a.m.	0·35
160 „ Liverpool	8.0 a.m.	0·35
131 „ „	6.0 a.m.	0·52
103 „ „	4.0 a.m.	0·52
74 miles north of Isle of Man	2.0 a.m.	0·70
	July 24th, 1866.	
46 miles from Liverpool	12.0 night	0·87
32 „ „	11.0 p.m.	0·87
17 „ „	10.0 p.m.	1·05
	Augt. 13th, 1866.	
Off Greenock	5.10 p.m. Augt. 15th, 1866.	1·40
Off Helensburgh	6.35 p.m. Augt. 13th, 1866.	0·875
Off Gourock	5.0 p.m. Augt. 13th, 1866.	1·22
Between Kirn and Gourock	6.0 p.m. July 30th, 1866.	1·22
Arrochar (Loch Long)	1.30 p.m. Augt. 15th, 1866.	0·70
Off mouth of Loch Long	6.55 p.m. Augt. 17th, 1866.	0·875
Head of Loch Goil	1.5 p.m.	0·875
Entrance of Loch Goil	4.30 p.m. Augt. 1st, 1866.	1·05
Head of Holy Loch	2.45 p.m.	0·70
Middle of Holy Loch	2.30 p.m. July 31st, 1866.	0·52
Dunoon (several hundred yards from shore)	1.0 p.m.	0·70
Dunoon (about 800 yards from shore)	1.15 p.m. Augt. 16th, 1866.	0·70
Off Dunoon	1.0 p.m. Augt. 20th, 1866.	0·70
Stream at West Bay, Dunoon	1.0 p.m.	0·52
Stream between Innellan and Dunoon	12.0 noon Augt. 16th, 1866.	0·35
Between Innellan and Dunoon	1.8 p.m.	0·875
Off Innellan	1.15 p.m. Augt. 9th, 1866.	0·70
Off Wemyss Bay (high tide)	12.0 noon	1·05
Off Wemyss Bay (low tide)	4.30 p.m.	0·875

7191. (*Mr. Prestwich.*) What quantity of water do those numbers refer to?—I made the experiment simply upon 100 cubic centimetres, that is about 1,500 grains of water, and those numbers may be taken as simply comparative. I believe this gives a fair idea of the progress of purification of sewage water as it went down the river, and it shows that a considerable time is required to complete that purification which did not occur until the Firth became four miles broad, and until the water had gone down 22 miles. I think that is an important fact.

7192. (*Chairman.*) I understand your statement to be that a sample taken 18 miles below Glasgow was found to be equal, at that distance, to a sample taken six miles above Glasgow?—Yes, in its power of dissolving oxygen, showing how little it was aerated.

7193. Do you know at all what time would be occupied by the water travelling down from Glasgow to 18 miles below?—It is a tidal river, and it would be difficult to answer that question.

7194. It would oscillate, would it not, from one point to another?—Yes, it would take a long time; there are a number of things to consider in this matter. I do not call the examination I made complete. It is the examination of only the relation of the water.

7195. That rule which you applied to the Clyde, where there is salt water, would not apply to an ordinary river not being a tidal river?—No, it would not apply in such a case; it would not be the same in a river not tidal.

7196. Have you formed any opinion as to the probable distance and the time that the water would require to purify itself, after being contaminated by sewage matter, I mean in an ordinary fresh water river?—It is rather a difficult subject, because it depends upon the size of the river, and the amount of sewage, and the peculiarities of the mud and bottom of the river. Some kinds of mud take down the organic matter much more rapidly. Altogether it is a very complicated question, and I doubt whether a rule can ever be laid down; every river would require to be examined for itself, at least for a long time to come, till we can get nearer the point. I have a few facts

which I intended to mention to the Commission about the Thames, and I may say that I have a few about canals. I know that in 16 miles of flow of a canal near Manchester, the organic matter was still sufficient to make the water appear not very agreeable, but still I could find scarcely any ammonia in it. Putrefaction had taken place, and the ammonia had nearly evaporated in the 16 miles.

7197. Have you followed out that idea with the view of ascertaining whether sewage can be detected at 18 or 20 miles from the point of discharge and pollution?—In the flowing canal to which I alluded the water had lost all its richer manurial qualities in 18 miles, but had preserved offensiveness enough to prevent it being used to drink. I may say what I found in the Thames. Above Reading very little impurity was found in the Thames, but below Reading it was very marked indeed, and it never disappeared in any part below Reading.

7198. (*Mr. Harrison.*) For what distance down?—Any part. I went down to London Bridge, and it was visible in any part below Reading.

7199. (*Chairman.*) Did you detect the presence of sewage from every sample that you took below Reading to London Bridge?—Yes, what I believe to be caused by sewage; it was organic matter, which in its decomposition showed a great deal of animalcular life, and which I believe to indicate so much organic matter of a very active kind, probably dangerous.

7200. Supposing there had been no source of contamination below Reading, would you then have been able to detect the presence of sewage in the river, because, as you are aware, down the river there are fresh sources of contamination going on?—Yes, I think there would have been a little. I may say that above Oxford I considered the water extremely pure, but below Oxford, and I might say down to Pangbourne, it was, perhaps, a little less pure, but very little. I considered at that time that it was not proper to take water from any source below Pangbourne at any rate. Perhaps I might be inclined to go higher now, but that was my view at the time when I examined the water for the Metropolitan Sanitary Commission, which is now 20 years ago nearly.

7201. Are you of opinion that a water once affected with sewage contamination is never after a safe water for domestic purposes?—I think it may be quite safe. It is so in some cases, in others not.

7202. Under what condition?—Supposing it were very impure indeed, the first thing that would occur would be putrefaction; that gives out a number of nauseous gases, and the most prominent to the senses is, perhaps, sulphuretted hydrogen. After the putrefaction had finished a great deal of the organic matter would be removed. If any remained, and it were exposed to oxidation, nitrates would be formed. Those nitrates are, I consider, so far offensive as they indicate very bad company, but in small quantities I am not aware that they can be considered hurtful. On the contrary, to some extent they are a very valuable accompaniment of organic matter. They themselves are disinfectant and prevent processes going forward which would be unpleasant.

7203. What are the dangerous associations of nitrates?—They, with some uncertain exceptions to be spoken of, indicate that organic matter containing nitrogen had been present, and ready to give out unpleasant, and, I suppose, dangerous forms of animalcular life; but when the organic matter is perfectly oxidised I suppose these forms and substances do not exist any longer. There are two modes which we know of destroying organic matter in water; one is by putrefaction. Putrefaction takes off the organic matter chiefly unoxidised. The carbon and hydrogen come off both unoxidised, and carburetted hydrogen appears and hydrogen alone. That occurs when there is very little air, but if there is a great deal of air in the water oxidation takes place, and nitrates are formed, and the organic matter is then taken off in combination with oxygen. That is the process which takes place when water is evaporated into the atmosphere and thoroughly oxidised. We may say here that the organic matter is evaporated into the large supply of oxygen contained in the water, and there it is thoroughly oxidised. The processes are entirely the same, and the destruction that takes place is accomplished by the same means, namely, oxygen, whether in the air or in the water. It may even go further. After nitrates are formed they may be taken up by the soil, because nitrates are food for plants just as ammonia is, and the very last trace of nitrogenous organic matter may be removed by plants, so that nothing whatever remains of it except those parts which were accompaniments and now are inorganic salts.

7204. Is it your opinion that after the application of sewage to the land the water filtered off and running into the river would be harmless?—If the land or the filter is not overburdened with sewage, that is to say, if no more is allowed to pass through than can be properly oxidised, then complete purification must take place. There is no water, I suppose, so free from organic matter as that which comes from deep wells. It is entirely a matter of depth, or rather, I should say, it is a matter of time, because the use of the depth is merely to keep the water in contact with the soil for a longer period. If the water is kept in contact with the subsoil for a long period without depth the same thorough oxidation must take place, but if the water is drawn rapidly through the soil the oxidation is incomplete, and only a rude filtration of the water will occur; that is to say, straining the water, which is imperfect filtration.

7205. If the earth is in a condition to filter, of course it would catch all that is in mechanical suspension, but would it equally catch all that is in solution?—Not equally, that requires considerable time. You must either have time or depth; long contact with the soil is necessary. The porous soil is the agent for transferring the oxygen.

7206. Then, as a rule, are you of opinion that it would be safe to apply sewage to land and allow the water to run off into a river which is the main source of supply to a town for domestic purposes?—It is certainly safe to apply some. I am not able at this moment to say how much. I am not able to say, considering to the new plans of irrigation proposed, that it would be proper to load the neighbourhood of a large town with sewage, and collect the water from it and use it for the town. I am inclined to think that it would not be safe; but in a thinly populated agricultural country I think we have no reason to believe that any danger can occur. In fact we may say that there is no water except of this kind to be got in any part of the country, even on the hill tops; it is simply a matter of quantity. The hills have the sewage of a very large sheep and cattle population, we may say, and that sewage is either passed under the soil or it is taken off as surface water. If it is taken off as surface water we seem to be very well satisfied with it, and the Loch Katrine water may be said to be of that class. If it is passed under the soil it is certainly very perfect, and would be probably the best that we could possibly attain; but we have no very large quantities of such in existence in the country so far as I know, so that the surface water of the hills may be said to be very dilute sewage water. I therefore conclude that it is a question of quantity, how much sewage can be put upon the land.

7207. Then you are of opinion that sewage may be safely applied to land if it is not in such a quantity as to master the filtering power of the earth in which it is placed?—I believe that to be a proper way of expressing the limit.

7208. Will you have the goodness to proceed with the statement of your views as to the action of organic matter?—Perhaps I might put it in this form: the third class of organic matter I have subdivided; two of these divisions are decomposing matter, containing nitrogen, and permanent organic matter containing nitrogen. These are the most dangerous substances, and these are estimated when the organic nitrogen

Dr. R. A. Smith.

April 1868.

is taken. Professor Frankland has made their estimation a regular part of a water analysis, and Professor Wanklyn has, by another mode, done the same. The great question seems to be what is their importance.

7209. Have you tested Professor Wanklyn's process?—I have made a few experiments with it to see if it is correct, and I am inclined to think that his experiments in principle are correct, but I have not done enough to be certain. I consider that I attain the practical end by a different method I now say that if the decomposition is such that no putrid gases are formed, we are unable to find any harm done by chemical action. Next, if the water contain substances which prevent putrefaction, as, I believe, is the case when peat is present, the amount present of organic nitrogen can do no harm. The organic body may be compared to japanned leather in comparison to putrid hides. From the first we can drink pure water, but from the second the water is offensive and dangerous. I was led to that by finding so much ammonia in the mountain waters. I find that Dr. Frankland has also found more organic nitrogen in those mountain waters, and Professor Wanklyn has found the same; but on exposing those waters to a temperature which would bring out the organic forms, that is, animalcular life, I find that the mountain waters show very little, and sometimes none. I conclude that the substances which are present in the mountain waters prevent decomposition. They are anti-putrescent, or they are disinfectant; perhaps they contain organic matter like a mummy, or perhaps in the form of leather or some such form; at any rate, we do not find that decomposition which we may call dangerous, and that decomposition which produces offensive looking animalcular life: for that reason we drink them freely and we inquire no more about it. We pay but little attention to microscopic inquiries about such waters; and we do not consider if this nitrogenised organic matter may be in a condition ready to receive and to develope organisms, or be ready to take disease by infection as it were. We cannot tell its character without examining if it is so. We must expose it to conditions favourable to the growth of the lower forms of life. If nothing appears under the microscope it is well, that is to say, it is sufficient. If something appears we must then compare the results with those obtained from pure water, and water believed to be bad. The amount of development of vital forms will not, so far as I know, correspond exactly with the amount of organic nitrogen. I think that one of the most important points to bring out. I think that experiments completely show that water may contain more organic nitrogen, and still be considered perfectly innocent and pure, that is free from hurtful impurity, such as mountain water. When we have gone so far we find our difficulty; but we must be satisfied to act upon our knowledge. I have a considerable confidence in the general facts observed by me long ago, indicating that the animalcular life increased in coming down the Thames, and that the amount of locomotion and evident vitality and flexibility in the forms were indices of the impurity or of the condition of the organic matter. We have never heard, for example, that a water containing only a few of the common diatomaceæ in the upper part of the Thames could hurt anyone. The evidence is yet to be found. In the cisterns of London the animal cular life is abundant; and as the density of the population increases the carelessness as to receptacles increases, and the microscope reveals disgusting sights. These contain organic nitrogen which is to be feared. The peaty water of it contains more nitrogen, leaves the pebbles in the lakes or rivers free from animal or vegetable life almost entirely. We cannot, therefore, compare the amounts in the two waters from the plains and from the hills. They are either not of the same kind or they are not in the same condition, that is to say, the organic matter is either not of the same kind, or it is not in the same condition; it may be less in quantity but worse in quality. In the next place I may say, if we can see nothing with the microscope and can find nothing by chemical analysis, have w any right to fear anything else? There are the germ remaining; if we can see no germs, and cannot prov that water from any one particular district or of particular class produces disease, what is it that w fear? The cattle on the hills have diseases as th cattle upon the plains, and there are numerous insect upon the hills. It must be a question of quantity tha makes us admire hill water, but not one of quality, so fa as the purely agricultural part is concerned. In othe words, we have a similar material in hill water but les of it. If the quantity is much less the hill water i taken down unfiltered, whilst the plain water is to a great extent passed through drains. The first is brown, the second purified until it is without colour. The question of quantity may be given up if the hill water is not filtered, and probably if it is filtered, but I consider that this is one of the points which requires examination. If the amount of germs is only a question of quantity they are much more likely to be removed in great quantities by the soil filtration, and by the filtration of the water companies, than by no filtration. I believe, however, that we have no right to fear that which has passed slowly through the soil. Germs, however small, seem to be retained by the soil, which takes up even smaller substances, namely, salts in solution and gases; and water from deep wells is purer even than most rainwater with us. If the germs pass into rivers we do not know how far they may be carried; on the other hand we do not know that they ever can be carried in pure water; the dissolved oxygen may destroy them, as it unquestionably does putrescent matters. A positive proof of their transmission in otherwise pure water is wanting. We might ask if a cholera germ in the water at Oxford would produce disease in London; and we might answer by asking if one cholera germ passing into the air at Woolwich would produce disease in Pimlico. This we do not know; but it seems probable that disease cannot be carried far by pure air or by water with much oxygen in it, which is equal to pure air. We are informed that the atmosphere is full of germs, but the evidence seems to be that it requires an unusual excess to attack us successfully. It seems to be a question of quantity. Still there is the sentiment remaining; we do not like that any sewage should enter the water that we drink. I am disposed to think it well to listen to this sentiment, so far as large towns are concerned, although even then we must remember distance and quantity; but so far as villages and ordinary agricultural drainage is concerned, I am not aware of any experiments showing sufficient room for fear.

7210. Is there any other point which you desire to bring before the notice of the Commission?—Yes. Another point is that the sewage from the plains is greater than that from the hills. This, then, goes against the plains, and the question simply is how much sewage will land bear. We must examine the water as mentioned to be certain. It seems to me that we must keep to actual knowledge; beyond that there may remain a sentiment, which sentiment I have strongly; but perhaps it would be difficult to induce people to spend millions upon it. After all that is said the inquiry must take place, as it seems to me, into the condition of the organic matter in the Thames waters, and especially the upper valley of the Thames, comparing the water from the hills at the same time. Until we receive that information it does not seem to me that we are in a condition to settle the question. I do not know whether I have quite explained my views. We require to examine into the condition of the organic matter containing nitrogen in the waters of the Thames, and the condition of the organic matter containing nitrogen in the hill waters, before we can give an opinion. It is not the mere amount of organic nitrogen that is of the greatest consequence, but the condition of that matter, whether it is in a state ready to putrify or give out germs of life,—vital forms. If there is neither putrefaction nor vitality I do not see how it can affect us.

7211. At present is it not the case that we have

really no positive evidence of what is called cholera germs, or the germs of any other disease?—Nothing precise. I believe it is proved that water of that kind, which we do find in many of the cisterns in the east part of London, will produce disease; and I suppose the proofs that Dr. Farr brought forward to this Commission are sound; and many other things show that the cholera was assisted into the east of London by such means as he mentioned. But in all those cases the water was visibly impure, or at least, by carefully nursing these germs of animals, they might have been seen by the microscope. I mean that so far as I understand the condition of the water of which Dr. Farr speaks, it was a water which would have produced animalcular life, although I did not examine it myself. I have, however, examined the waters in various parts of the east of London and the city; the water found in cisterns by no means resembles the water supplied by the water companies; and I could believe in any amount of disease produced by the use of such waters as were in some places seen. The forms of life which they show are very disgusting, and I believe that such forms simply show a great deal of unwholesome and dangerous matter. However, I am not a microscopist myself, although I have given a good deal of time to microscopic inquiry in connexion with water. I should be glad to see that subject examined by a microscopist.

7212. Did I correctly understand you to say that the presence of coloring matter in the peaty water had a tendency to arrest decomposition?—The presence of some matter in peaty water has that power.

7213. Does it amount to more than that; does it destroy animal life?—I am not quite sure whether it destroys animal life. I am inclined to think that it causes the organic matter to undergo decomposition in a different method. Peaty matter, for example, is always giving out ammonia; at least I have always found ammonia in the peaty water, and I suppose that this ammonia comes from the organic substances containing nitrogen, and, if so, they decompose in a manner somewhat different from that which we find in the waters of the plains. I am not quite sure as to the method.

7214. Apart from the question of cholera are you of opinion that peaty water would be injurious to health?—As a rule it is not, I think it may in some cases be so. although I have not heard of its being injurious on a very great scale. When I was at Oban last year I met Dr. Frankland, and he informed me that the water of Loch Ness was very hurtful to some persons. That rather agreed with some ideas that I had previously had that there was, in some kinds of peaty water, a substance which to say the least was not agreeable. In some peaty water there is an acid formed of a rather bitter taste; if the water is kept in a pretty close vessel for a long time the taste becomes very powerful. I tried this experiment with a specimen of the water from the upper part of the Clyde, which was very brown. I may say it was two or three years in my laboratory, and this process took a long time to go forward. The Glasgow corporation was at that time considering whether it should supply the town from the upper part of the Clyde. The acid formed in the peat is not volatile; at least the solution becomes stronger by boiling. I believe it would require a rather large amount of albumen to overcome this substance, that is to say, to decompose notwithstanding its presence. In some cases the taste is very decided in the mountain waters. It is to this that I attribute the fact which I learned from Dr. Frankland. I suppose this acid to be removed by being oxidized when in open lakes, or when it runs very far. I am not sure of that point, however, the bitter acid did not show the properties attributed to humous acids. Some peaty matter evidently falls down when it is exposed in large lakes or runs far, being rendered insoluble, perhaps, by the early stages of oxidation. I have no proof, however, that the whole of the acid is removable by the atmosphere from waters such as that of Loch Ness, in which you can taste the bitter, but I am quite sure that it is entirely removed by deep filtration. I conclude, however, that the organic substances in the mountain and the plain waters are either different or in such different company that, by comparing the quantity, we cannot draw conclusions as to their effect. I had at a former time expressed an opinion that peaty water was not hurtful. I always knew that it was not pleasant to the taste, but I did not know until lately that it might be hurtful to the stomach, causing a little diarrhœa, and for this reason I would not recommend every class of peaty water; there are great varieties. I think peaty waters might be divided into several classes after my late observations. In the water from the clay slate also there is sometimes found another substance, called chloride of calcium, which does not seem to be noticed by chemists; that also has antiseptic properties, but exists only to a small extent, although I imagine that sometimes it may be tasted in waters. Those are points which require a little examination regarding mountain waters. A great deal of the mountain water is from the surface; that from the plains has been much deeper in the ground, as a rule, and has therefore been freed from the decomposed vegetable matter and manure with which it came in contact. No water is so free from animal matter as that which passes through a great depth of soil. The soil oxidises more thoroughly than the air alone, at least more rapidly; and therefore well water is universally admired, whether hard or soft. The air in it would be found to contain from 33 to 34 per cent. of oxygen, whilst that is seldom the case in mountain waters, although in some it is very nearly as high. In the Loch Katrine water, and in some waters from Wales and Cumberland, Dr. Frankland has found it very nearly as high; but a knowledge of the amount of oxygen in the Thames water is much wanted; the rapidity of the oxidation which is going on is not at all known. If the water is found to-day to have 30 per cent. of oxygen in the air which it contains, and to-morrow to have only 12 per cent. of oxygen, or anything less than 30 per cent., it shows that oxidation is going on, and I look on that therefore to be another of the important methods by which the organic matter in water ought to be tried. I have sometimes found the oxygen in the absorbed air in the water to differ as much as from 33 and 34 down to nothing. If there is none at all it is a certain proof that the organic matter is absorbing the oxygen of the air, and there must be a great deal of impurity; if there is 33 per cent. it shows that this process is not going on, and that there is no evidence of oxidising impurity. It requires, however, to be considered whether this oxygen from the air is taken up by peaty matter or not. I believe that the peaty matters also absorb oxygen. I have examined a reservoir about 20 feet deep, containing peaty water, and I have found the upper surface of the water to contain air, having about 26 per cent. of oxygen, and the lower portion, about 20 feet deep, to contain air, having 12 per cent. of oxygen, showing I believe that the peaty water was absorbing oxygen, and purifying and decolorizing itself in that way. I do not think that there is a great deal to be feared from the peaty matter. I only mean to say that it must be more examined than hitherto, because I think most people would complain if a water, tasting like the water of Loch Ness, were introduced largely into towns, unless it could be shown that a modification of this taste were to take place during the storage or passage into the cisterns or pipes for supplying the houses. I have observed a similar taste in many other parts of Scotland and also in Cumberland.

7215. Taking the Thames in its present condition, and having regard to the recent Act of Parliament (the powers under which extend, as you probably are aware, up to and including the town of Oxford), which requires that all the towns should intercept their sewage, deodorize it, and apply it to the soil, when that arrangement is carried out and the sewage intercepted, are you of opinion that the river Thames would be a reasonable source of water supply to this metropolis, and a safe one?—

Dr. R. A. Smith.

2 April 1868.

That is an important question. I do not think that I could come to a conclusion in my own mind without a greater knowledge of the upper portion of the Thames than has yet been attained by anyone, so far as I know, and knowledge acquired in the direction which I have indicated here; but my impression is that it would be safe at some point. I do not know exactly that point. I think that the point ought to be certainly above Reading at least. Some years ago I thought of Pangbourne; but now, from the increased population, and perhaps some differences in the mode of draining the land, probably the point should be removed higher up the river.

7216. Supposing the sources of contamination were cut off, would that point then be so important?—I am considering the sewage of Oxford to be entirely separated. We should have, I suppose, then only agricultural sewage and village sewage, as there are no large towns on the Thames. My sentiment is rather against sewage, and therefore sentiment inclines me to drive the point from which the water might be taken very high up. But leaving the sentiment entirely out of view, and looking at the results obtained by chemical analysis and the microscope—I confess that I see no distinct reason which would compel us to leave the bed of the Thames for water, so far as organic matter is concerned. But the upper streams must first be examined.

7217. Having your choice, apart from the question of cost, would you elect to have the water from the Thames in preference to the water from the sources of the Severn, or from the lakes of Cumberland and Westmoreland?—When the water from the hills has none of that bitter taste of which I speak, and has none of the peaty colour, I should prefer it very much before the other water.

7218. I presume, for manufacturing purposes, you would have no hesitation in preferring a soft water?—It is very important for manufacturing purpose. I was speaking only of drinking and cooking purposes at the time.

7219. You have had a great deal of experience of the use of water for manufacturing purposes for dyeing and scouring purposes?—Yes.

7220. And you give the preference to soft water?—Yes. I have found that a very minute quantity indeed of salts producing hardness were hurtful in some dyeing processes as I considered.

7221. Have you formed any idea as to the saving of soap occasioned by the use of soft as compared with hard water?—I have adopted Dr. Playfair's calculation in that case. I have not made one for myself. I have no doubt that his is correct.

7222. Has that in your experience been confirmed?—I would perhaps not give such a high number as Dr. Playfair, but he is far in the right direction I have no doubt.

7223. (*Sir B. Phillips.*) Do I rightly understand you to say that you have examined the water in the districts at the east end of London?—Yes; I did so a long time ago.

7224. And you found them to contain decomposed and dangerous matters?—Yes; the cisterns I found very impure.

7225. Supposing that the waters, say from the lakes, were delivered into cisterns in the east of London in a perfectly pure state, would they not by contamination become decomposed and dangerous?—Yes. I know that the water that was delivered into the cisterns at the time of my examinations was infinitely purer than that which existed in the cisterns.

7226. Then it is your opinion rather that the impurity arises from the contamination when in the cistern?—Yes, from conditions connected with remaining in the cisterns. I believe that is quite certain.

7227. And not the water itself?—No; although I still think that the water is taken too low down the Thames, to say the least.

7228. (*Chairman.*) Has your attention been directed to the question of a constant as compared with an intermittent system of supply?—I have given it some attention, but I do not know that I have anything to say very peculiar upon that point except that I agree with those who believe in the great importance of a constant supply, for this very reason, that it would avoid the contamination of storing; I think that a very strong reason so far as London is concerned.

7229. (*Mr. Prestwich.*) You have been considering the waters, have you not, with reference to the organic matters present in them from the point of view of their value as drinking waters apart from the consideration of the presence of any mineral matter?—Yes, I have.

7230. I presume that you have directed your attention to that part of the subject more especially as being an important consideration with respect to health in the supply to towns?—Yes. I have a few notes regarding other substances, but they are of less importance.

7231. You have divided the organic matter in water into two heads — organic matter containing nitrogen, and organic matter without nitrogen?—Yes.

7232. Did I correctly understand you to say that it was with reference to the condition of the nitrogen in these waters that their value depended for drinking water in a town?—Yes, the condition of the organic matter containing nitrogen.

7233. I notice that in the analyses which have been made by Dr. Frankland of the waters from the Thames and the water from Loch Katrine, and from the Welsh district, and from the Cumberland district, the quantity of organic nitrogen does not vary very much in those different waters?—No.

7234. But do I understand you to state that the same value is not to be attached to organic nitrogen in the waters from the mountain districts as to water from the river Thames and so on?—That is my opinion.

7235. And therefore, though chemical tables shows like quantities, you consider that the qualities should be shown separately?—Yes.

7236. May I ask you in what way do you look an it and determine the value of this organic nitrogen it those two systems of waters?—If a certain quantity of water is allowed to stand at a temperature favourable to the development of the lower forms of organic life, it will be seen which water prodnces the most, and whether the quality is different in the different waters. The probability is that mountain water will show little or nothing, and the plain water may show a very decided amount, so far as I know; it certainly will in the lower part of the Thames, but it will not at the very beginning of the Thames—for example, at the Seven Springs, near Cheltenham. But I think it important to try that experiment on all the waters, and compare the animalcular forms which are developed in each.

7237. I see that in the water supplied to Manchester the quantity of organic nitrogen is ·026, and the quantity in the Thames water delivered by some of the companies is ·011, therefore less than half the quantity in the Manchester waters; but, notwithstanding the quantity which you have in those Manchester waters, as shown by chemical analysis, you seem to think that there are other points to be considered beyond the mere fact of the presence of organic nitrogen?—Yes.

7238. As you reside in Manchester, you are well acquainted with all the properties of the water there. Looking at those two waters as keeping waters, supposing you were to place them both under the same conditions, and both under a certain exposure, and to keep them for a long time, have you any knowledge of the result which would be produced in the two cases?—My opinion is that the mountain water will keep best.

7239. The water supplied to Manchester is collected upon the hills?—Yes, on the hills between Lancashire and Yorkshire.

7240. How does that water keep?—I have not had occasion to keep any of that water so long as some of the other waters. I have kept the waters from the Scotch hills when I was making an examination

for Glasgow, and I have also kept the water from the Thames when I was making the examination for the Metropolitan Sanitary Commission; but I have not made the same experiments so carefully for Manchester; I never knew of any large development of animalcular life from the Manchester water, except when it comes down muddy, which has been the case lately. I think they have been making some changes in the works, and it is difficult in such a case to compare it. However, as a rule, I believe the mountain water will keep very much better than the plain water above alluded to. I feel satisfied of that.

7241. You were mentioning some of the results you obtained from an examination of the Thames water which you made some years ago, taking the water above certain towns and below certain towns, with regard to the extent to which the water becomes oxidised and purified after a certain length of flow; could you mention those results?—There were a few points in the report published by the Sanitary Commission which I would mention. I say in that report: "The Thames water is at first pure as far as freedom "from organic matter is concerned, and takes its course "through a rather level country. The stream is soon "filled with plants, and at Kemble the water has "already taken up some organic matter, enough to "form a slight green deposit on standing. The water "here is still beautiful and clear, and is good water. "It is 15·5 degrees of hardness. When we come "down to Pangbourne the water cannot be said to "have become much worse. It is still so pure as to "require a considerable time to form a deposit, and "that only small, containing a few plants and some "small animalcules from $\frac{1}{2000}$ths to $\frac{1}{3000}$ths of an inch. "Here is a slight, but still decided trace of organic "matter from animals. There has been an increase "in the hardness also."

7242. Are we to understand you that you would be guided as to the objectionable quantity of organic matter in water rather by the results showing the development of animalculæ than by the results of chemical analysis?—I think that one of the most important experiments that can be made, although I would not neglect the others. I have seen some very striking instances, indeed, in which an enormous number of animalcules have been found in water which at first appeared perfectly pure, and quite a contrary result has taken place in water which I thought to be inferior.

7243. Both waters showing the presence of organic nitrogen, but giving rise to different living organisms?—Yes. That is nitrogen, which I suppose we must call organic; formerly I imagined it to be inorganic from these peculiarities which I suppose to exist.

7244. I understand you also to say that if you give the water a sufficient length of flow this organic matter will be oxidised more or less completely?—Yes, that is always the case. It is a question of length of flow, or length of storage, or depth of drainage; those are the three most important points.

7245. Do you consider that the presence of nitrates or nitrites is an indication of sewage having previously existed in the water?—Whenever the original water was free from nitrates, the nitrates in the succeeding flow of water may be taken as a proof of previous sewage, and more than that, I should say that they were the minimum of previous sewage, because some may have disappeared entirely. For example, though the upper part of the Thames showed no nitrates whatever, and the lower part of the Thames showed nitrates, we may say that they indicate a certain amount of sewage which had flowed into the Thames; but there may have been much more passed into the Thames which has not appeared in the form of nitrates.

7246. Might not that also to a certain extent arise from vegetable matter as well as from animal matter?—Yes. The nitrites and nitrates are formed from albumenoid matter decomposed, whether arising from animals or vegetables. I have endeavoured to tell whether it comes from animals or vegetables, and I think in some cases we are able to tell.

7247. By what means?—The nitrates are what I have called old organic matter. There is no doubt that by the oxydation of nitrogen compounds nitric acid is formed. I imitated this process long ago, using chiefly yeast, and so produced nitrates from yeast or vegetable matter The nitrate comes from animal and vegetable albumenoids indifferently. When estimating the London sewage we may readily refer most, if not all of it to animal matter or sewage. In the river above London some of the nitrates come I do not doubt from vegetable matter. I have not estimated how much comes from one and how much from the others. I am inclined to think that nitrates coming down may be divided into the animal and vegetable nitrates, and measured. Albumen, &c., would produce nitrates without being used by animals. When nitrates are caused by matter from animals there is always a corresponding amount of common salt. Men take from 200 to 300 grains at least of common salt every day, and it is given out every day. This is the most unchangeable accompaniment of sewage. By it we may know how much sewage has existed, and how much of it has evaporated, if we know the original amount of water. By looking for this substance alone we may trace with great rapidity the increase of actual sewage in the Thames, and we may save ourselves some horror by remembering that some of the nitrates may be derived from vegetable matter. I do not doubt that all grass will give out this oxidised nitrogen. The amount of chlorides in sewage is somewhat about five per cent. of the dried matter, and the London waters contain about four-tenths of a grain per gallon more than the Manchester water. If all comes from sewage it would indicate a large amount, perhaps from 800,000 lbs. to 1,000,000 lbs. per day; but I do not think this calculation is of much value till I look into the details. This matter does not all come into the water, only the salts and such organic parts as escape filtration and oxidation. Nitrates act as manure; they are therefore decomposed. They do not therefore necessarily give the whole truth. If the original matter is free from nitrates, these accumulating, give the minimum of previous sewage. This remark will apply to Dr. Frankland's numbers, which would be the minimum of previous sewage in waters which had at first no nitrates. They cannot, therefore, be exaggerations if done with his usual accuracy. There are some difficult cases to explain where nitrates appear when we cannot find sewage. The nitrates from old beds of nitre would be scarcely considered as indicating previous sewage, as the animals have been so long dead. But there may be modes of forming nitre in the earth, as there is certainly in the air, without sewage. This difficulty cannot be said to appear in the case of the Thames water, at least the examination for chlorine would check it. There are said to be nitrates from many of the deep wells in which we cannot trace sewage. I do not understand that subject; I think it requires attention. We may say, why do we dislike nitrates, since they indicate aeration? They are disliked because of their previous bad company. They have been in contact with sewage when they can be shown to be formed recently. If, however, we are sure that the company is to be kept out we do not require to be afraid of such reformed characters unless they become personally offensive. As to their becoming personally offensive, I made a few experiments some time ago, and I thought that I could taste $1\frac{1}{2}$ grain of nitrate in the gallon, sufficiently to render the water vapid and insipid, but some more delicate tastes may be affected by a less amount than $1\frac{1}{2}$ grain. I think the analyses given by Dr. Letheby indicate one grain in a gallon as nearly as possible. Many years ago, at the time that I speak of, when I examined the Thames water from Westminster up to the sources, I found nitrates at London in such abundance that on heating the residue red fumes rose up from the crucible. Many years before that it was noticed by Dr. Lambe, and given in a parliamentary

Dr. R. A. Smith

2 April 1868.

report of the time. His analyses, however, generally do not seem correct. Five or six years after my first inquiry I think it was, on examining the waters of the Thames when they had become so offensive that measures were taken to disinfect them, the nitrates had nearly or wholly disappeared. That was the case with the water opposite Westminster. The putrefaction had superseded the wholesome oxidation of the nitrogen. The formation of nitrates is the safeguard of our towns. Without this process of the formation of nitrogen we should be living upon a bed of corruption; still, I certainly should prefer them not to exist in water. By going higher up the Thames we should no doubt get rid of a great many of them. But we might be asked this question, When are we to fear them? We are to fear them when we are not sure of the extent to which the organic matter will be supplied for their formation. In wells, therefore, when we do not know the source of the water, we must fear them; and small supplies of nitrates in a well near a house indicate sewage which has overflowed, and if nitrates are found there I think attention ought to be paid at once to the matter, and the attention should not cease until the nitrates are removed.

7248. They are there because the water could not get them from any other source than sewage, as rivers can?—Just so; so that we have no idea at what point the passage of sewage matter into a well will cease in that case, and therefore, whenever nitrates are found in a well, I recommend people to remove the cause. In deep wells they remain pretty constant, I believe, and we know their limit, so that we have not the same fear then. In river water which is to be filtered we require to be constantly watchful when nitrates appear, lest the organic substances should escape before being converted into nitrates. That, I think, is important. We must fear them also when they have a decided taste, and at a point which medical men may consider to be sufficient to do injury; but the latter point, I believe, has not yet been ascertained. They are often found near graveyards in enormously large quantities, so much so as to affect the taste strongly. It is a curious fact that many of those graveyard wells are rather popular, and the taste does not seem to frighten a large class of people.

7249. You take the presence of nitrates to indicate the possibility of a dangerous origin?—Yes.

7250. Not that they are in all cases to be referred to that origin, but that they are to be referred to other sources besides sewage?—I think the other source, however, is not of very great consequence. I believe all the great sources of water which are likely to be used for London or large cities will have no nitrates, or only very little, and the nitrates that do appear lower down the Thames may be considered as arising from organic substances still imperfectly oxidised, and are therefore so far objectionable.

7251. At the same time do I correctly understand you to say that sewage contamination may take place to a great extent, and yet the water may not show the presence of nitrates?—Yes; the nitrates may be completely removed, although, as a rule, they are only partially removed.

7252. We know that in some rivers and in some lakes nitrates are almost altogether absent, and yet you can hardly suppose but that water flowing into rivers through populous districts, or water supplied to lakes from hard rock surfaces where there is a certain amount of sewage from animals or from a scanty population, must contain a certain amount of sewage matter which may have been got rid of in other forms than that of nitrates?—Yes. If there is a great deal of sewage matter the nitrates, it seems to me, do not appear; putrefaction takes place and oxidation, and the organic matter goes off in the gases of putrefaction, and vegetation takes away the nitrates; there may be another mode of taking the oxygen from the nitrates, but I have only observed those two methods.

7253. In most cases where there is danger to be apprehended from the presence of nitrates have you not been able to detect the presence of chlorides?—Always. Whenever chlorine is high in the water it is necessary to look for nitrates derived from sewage, and, as a rule, it is so constant that there is scarcely any exception. When we find much more than the average quantity of chlorine in a well water, nitrates are found also, and if the water in a district is pretty well known, that is to say, if the amount of chlorine in water from any district is pretty well known, and a specimen of that water should indicate rather more chlorides than usual, you may conclude with almost certainty that it is from sewage.

7254. Can you tell us whether the quantity of organic matter in the water at Manchester varies very much at different periods of the year?—I have not made very many experiments lately upon the water at Manchester, but it certainly varies in colour. I have not, however, been able to say whether it was from what may be called the regular supply, or the supply that is going to be the regular one, on account of the operations going on at the works. They have been doing a good deal of work I understand at the reservoir lately.

7255. Then you do not apprehend any danger from the presence of the organic matter from peaty land in water for drinking purposes?—I have not the slightest fear of any other evil arising from that organic matter beyond what was mentioned. The only point, I think, that requires much attention, with reference to purely peaty matter, is the bitter taste which I think is important to attend to, and the appearance.

7256. Would it be likely to become either deposited or oxidised in a long flow, such as would be the case from Wales or from Cumberland?—I believe it would be completely oxidised either in the long flow or in large reservoirs. But I mention that because I think it is a point which has not received any attention, and it requires a little more attention than I have given it. Probably any new supply would require to have a considerable number of experiments made upon it. All peaty matter may not be removable by oxidation. I think it would be safe, but in such an undertaking we must take nothing for granted.

7257. Would it at all affect the aeration of the water by the time it reached London?—Oxygen is restored rapidly by absorption from the air, if time and surface are sufficient. I do not know very well the waters of Cader Idris or Plinlimmon. I know those of Bala Lake, which I examined at one time when Mr. Rawlinson thought of taking it for the supply of Liverpool, but those were rather brown. Perhaps the Bala water as it exists in the lake would be rather brown for the London people, but it would purify greatly.

7258. Are the Manchester waters and the Loch Katrine waters, as supplied to Glasgow, well aerated?—Yes, they are very well aerated. I do not think they are so bright as the chalk waters, but I believe Glasgow water is always free from colour; Manchester water varies, although there are portions of the Manchester district which give almost absolutely pure water. Dr. Penny found 33·6 per cent. of oxygen in the absorbed air of Loch Katrine water, and found above 27 in Manchester.

7259. In selecting a water for drinking purposes, what qualities should you consider the most desirable to look for, apart from other considerations and other purposes in the use of water?—So far as taste is concerned, I must say that I have no objection to a hard water, and, taking the opinion of other persons and the public generally, I should think that, as a rule, water with a little lime in it was rather liked; but then I consider that very little custom makes us extremely fond of the mountain water, and in an abstract point of view, without considering opinions at all, I should say that the mountain water was the best, simply because there is less extraneous matter in it. We like to drink pure water and any other matter which we wish to take besides water we can add according to our pleasure; it is better not to be compelled to add it in every draught of water, so that abstractly I should be in favour of the mountain water.

7260. Have you been able to form any opinion as to the effect upon health of the use of soft water or hard water?—I do not think there is good evidence upon that point. I have heard of horses losing their appearance when they used hard water, and of persons of my own acquaintance who got indigestion by coming into hard water districts; but then I must say that those cases are somewhat balanced by people being rather disagreeably affected on going to soft water districts, and especially some of the hilly districts of the north.

7261. That depends a good deal, I presume, upon the previous habits of people?—Yes. I do not think that there is a great deal of evidence on either point. I do not think it is fair, in fact, to take the appearance of the population as any criterion. If we did so, we might find some arguments in favour of soft water. I should think that the tallest people in Great Britain are to be met with in soft water districts; for instance, in Cumberland, and probably in Aberdeen. I may say that the tallest people I have seen in Great Britain are in Aberdeen, which is a very soft water district.

7262. (*Sir R. Phillips.*) Are they the most muscular?—They are powerful people. At the same time if we take the death-rates from the Registrar General's reports, we find that the smallest number of deaths occur upon the other side of Scotland, in the western district, where also there is soft water; perhaps that shows that the water has nothing to do with the matter.

7263. (*Mr. Prestwich.*) Nineteen-twentieths of the population of Europe use hard water, do they not?—I suppose they do. The effect is a point about which it would be very interesting to get more information, but it is complicated with questions regarding climate; in nearly all cases the climate of soft water districts is different from the climate of hard water districts.

7264. Are not soft water districts generally mountain districts where they have the purest air as well as pure water?—Yes. I believe, however, it is quite possible for the blood to take up matter which is inorganic, dissolved in water. A common hen, for example, takes up lime in great quantities whenever it requires matter to form its shell; this is an argument to show that food does not require to be supplied in combination with organic matter, but it may be taken up in a purely inorganic form; and Liebig, in his lectures, told us of children who had not been supplied with sufficient phosphates or lime in their food, and who got an intense craving for chalk, as he called it, and picked it from the mortar from the walls. However, I think the food that we do take supplies generally as much lime as we want. I should like to say a word or two about some other salts, if I may be allowed to do so. The chloride test must be used with great care, but the presence of common salt or chlorides is a proof of sewage from animals rather than from vegetables, if we may use the term sewage from vegetables, meaning decomposition of organic matter in and on the ground. But there is another point also to be considered, namely, the sulphates. The sulphur in the albumen oxidises, and it forms sulphuric acid which again, combined with potash as sulphate of potash generally comes from sewage matter, or it may be converted into sulphate of soda, and the potash retained in the soil; silica comes also in sewage. In examining the Thames after the sewage goes into it, the amount of animalcules containing silica, or diatoms with a silicious covering, is enormous. I consider that all the silica from the bread used comes out in the form of those animals; they may be got in millions from one bottle of water if the putrefaction is not very strong. If the putrefaction is, however, as it has been often in the Thames, even those lower forms of life are destroyed, and they do not appear at all. In my early examination of the Thames water I found millions, as I said, but in my later examination, when the Thames was very bad, I did not find them. Those nitrates and sulphates and common salt together form a considerable addition to the total amount of impurity existing in the Thames water when it arrives far down; so that instead of, as at the very beginning, having the hardness and the inorganic matter exactly the same or nearly the same, about 15 to 16 grains in a gallon, we have three or four additional grains caused by those alkaline salts. This increases as we go down. I found at the same time that a very small amount of common salt as well as of nitrates had an effect in diminishing the flavour of water, although I forget the exact amount. The sulphates also affect the taste, but in a very much less degree. However, taking the three together, I consider that there is a perceptible inferiority of taste caused by salts alone in the water low down the Thames compared with the water very high up, or we will say above Pangbourne to an uncertain point, and especially when we go to the sources. When those salts amount to three or four grains they must not be quite despised; they must weigh something in the appreciation of the water as a source of supply to a town. In taking water from the hills it might be necessary to remove the colour by filtration. I have never seen the water from the district proposed by Mr. Bateman, but it might be necessary to remove the colour, and the question would be whether that could be done by natural oxidation, by storage, by running, or by filtration. I have tried many experiments upon filtering, and found that an inquiry was very much wanted as to the best mode of filtering. The animal charcoal which I used completely took out the colour, but I do not know how long it would last; it seems to have a limit rather too early approached. But I tried also at one time a filter made by Mr. Spencer, of magnetic oxide of iron, which removed the least trace of colour from the peat water in a very remarkable degree. It is some eight or ten years since I used it. I do not know whether he can make the filters now with the same degree of perfection which he had attained when he made that one. Those which I examined afterwards did not seem to me to be quite so good, but if he can make them as they were made originally, he could manage to take all the colour out of any hill water, and therefore that objection, I think, would be removed.

7265. Could that be applied on a large scale?—I do not know. I only mention the experiment that I made at the time. I could not exhaust the filter, and it seemed to me an important subject for further inquiry.

7266. Do you consider that there is anything to fear from the action of soft water upon lead?—There is something to fear, that is to say, there is a great deal of caution required. There is not so much to fear that we should be prevented from using soft water simply on that account; but I think it is important, when soft water is used, that there should be no lead cisterns whatever employed, and that the lead pipes should be as short as possible. There has been frequent occasion in Manchester to remark that lead was present in the water; it has been believed to do injury in a number of cases, and it has been necessary in some cases at least to shorten the pipes very considerably.

7267. (*Chairman.*) It is stated, with respect to the Loch Katrine water, that leaden pipes and cisterns very soon become coated with a substance which prevents all action of soft water upon the lead?—That is so stated. I do not find that the action ceases entirely at Manchester. I think the only mode which they have been able to find of getting rid of it has been by shortening the pipes. I have sometimes thought that in peaty water the peculiar acid which I mentioned may have had to do with the objection, but I have not quite proved it. I may mention that I was told lately that in France they have made earthenware pipes and joined them together with a cement which will stand 150 feet of pressure. I have not been able to see them myself, but if that is the case the question of lead may be put aside entirely.

7268. (*Mr. Prestwich.*) Have any instances come to your knowledge of any injurious effect from the presence of lead in the Manchester water?—There

Dr. R. A. Smith.
2 April 1868.

have been several instances where medical men have believed injurious effects to have been caused by the lead, and in several cases where there have been lead cisterns the effect has been very decided indeed; but there have been also several where it has been believed that the lead poisoning had its origin from the pipes alone—enough, at least, to render great caution necessary.

The witness withdrew.

J. Heron, Esq.

JOSEPH HERON, Esq., examined.

7269. (*Chairman.*) You are town clerk of Manchester, are you not?—Yes, I am town clerk of Manchester, and have been town clerk since the establishment of the corporation in 1839.

7270. When you first became town clerk of Manchester, I believe the town was supplied by private companies with gas and with water?—Not with gas. As far as regards the water, which was very bad in quality and very limited in quantity, it was supplied by an old company called the Manchester and Salford Waterworks Company. In 1845 the attention of the corporation was more especially directed to this subject; we were in a most lamentable condition, and it was quite clear that some complete change was necessary. Perhaps I may be allowed to state that about that time the second report of the Health of Towns Commission was published—a commission over which the Duke of Buccleuch presided—and which I have no doubt is familiar to this Commission, for in that report it seems to me the subject is almost exhausted; we found it stated that "the "importance of an ample supply of good water, "accessible at a price within the reach of the poorer "classes of society, and in far greater quantities than "have hitherto been furnished, is a subject worthy "of the greatest attention."

7271. Will you tell us the state of things in 1845, which you describe as being so bad that it was absolutely necessary for the corporation to devise some other mode of supplying the town with water. Did that arise from the large increase of population mastering the capacity of the private company's works, or was it from any other cause in reference to the quality of the water?—It really arose from the fact that the works were totally insufficient in every possible respect to supply water for the population that then and for many years past had existed.

7272. Where did they get their supply from?—There were only two small reservoirs, called the Gorton Reservoirs, situate about three or four miles from Manchester, the water supplying which was gathered from the adjoining district, which was to a great extent agricultural land, but at the same time mixed with a considerable quantity of most objectionable sewage, so that the water was both very deficient in quantity and excessively bad in quality. I think the utmost extent was from 3,000,000 to 4,000,000 gallons a day.

7273. What was the rate charged for the water of the quality which you describe under the old system?—I have not got that information.

7274. I presume they were supplying under an Act of Parliament?—Yes, under an old Act of Parliament.

7275. At all events, the quantity of water was insufficient for the supply of Manchester, and the quality was such as to render it absolutely necessary to seek for fresh gathering ground?—Yes, certainly. The price was very high, and it was supplied upon the intermittent system, and the quantity supplied was very deficient.

7276. Will you state the steps which were taken by the corporation in 1845, to secure a more efficient and a better supply of water?—I was about to state that we find these recommendations incorporated in the report of the commission of the Duke of Buccleuch, and that we sought to carry them out by an Act which we shortly afterwards obtained from Parliament. The report states: "It appears to be generally admitted "by witnesses examined before us, who, being them-"selves connected with existing water companies, "have had every opportunity of observing the effect "of the opposing interests of the companies and their "customers, that a copious supply of pure water cannot "be secured to the poorer classes of the community, "unless the duty of providing it is placed under the "management of some independent body. It should "be the duty of the local administrative body not only "to secure a sufficient supply for all the inhabitants, "but, by contracting with or purchasing it of the water "companies, to ensure its regular distribution at a "fair remunerating price." Another recommendation was—"With the view of ensuring a sufficient supply "and proper distribution of water to all classes, we "recommend that it be rendered imperative on the "local administrative body charged with the manage-"ment of the sewerage and drainage to procure a "supply of water in sufficient quantities not only "for the domestic wants of the inhabitants, but also "for cleansing the streets, scouring the sewers and "drains, and the extinction of fire. For this pur-"pose we recommend that the said body have power "to contract with companies, or other parties, or "make other necessary arrangements." A further "recommendation was—"We recommend that as "soon as pipes are laid down, and a supply of "water can be afforded to the inhabitants, all dwell-"ing houses capable of benefiting by such supply "be rated in the same way as for sewerage and "other local purposes, and the owners of small tene-"ments to be made liable to pay the rates for water as "we have already recommended in respect to drain-"age." The corporation at that time felt so satisfied that it was desirable to carry out those recommendations within the city of Manchester, that we determined to go to Parliament to take power to purchase the works of the existing company, and to go for a large scheme which we believed would be sufficient for our present and prospective wants. But we determined also to go beyond those recommendations, because we determined, believing that it was only right and just, to introduce the principle of a public rate, and I believe it was the first time that the application was ever made to Parliament to obtain power to levy, in addition to a compulsory domestic water rate, a compulsory public rate, payable in respect of all property of every description within the city. We applied to Parliament in 1847, and then and by subsequent Acts obtained power to carry out a scheme which is not yet, I am sorry to say, completed. In 1848 we went for a second Act, which was simply to enlarge the scheme which was proposed by the Act of 1847, and since then we have had to go for other Acts of Parliament to obtain additional power both with regard to the scheme itself, and also for carrying out in detail works within the city and the adjoining districts which we supply.

7277. (*Sir B. Phillips.*) By your Acts of Parliament you have the power of levying two rates, that is, a public or general rate and a domestic rate?—Yes.

7278. (*Chairman.*) Will you give us the substance of the section of your Act which enables you to levy a rate?—By a clause in the Act of 1847, the corporation are authorized and required to estimate and fix the amount of money that will be annually required to meet the expenditure in connexion with the distribution of water; to make, in fact, an estimate. In making out that estimate we have to give credit for all the amounts that we shall receive for water supplied beyond the limits of the city, within which alone the compulsory rates extend, either for domestic purposes or for trading purposes, as well as credit for all the money that we receive within the city for trading purposes, that is to say, for water that is voluntarily taken for trading purposes.

7279. Do you publish this annual estimate?—Yes, annually.

7280. Can you hand one of them in?—Yes, I will hand it in. (*The witness delivered in the same; vide Appendix.*) Then we are authorized, in order to raise a sum of money sufficient to defray the costs, charges, and expenses of supplying the borough with water, to make two rates—first, a domestic rate to be levied upon the occupiers of all dwelling houses within the city, and, secondly, a public rate to be levied upon the occupiers or owners, as the case may be, of all property of every description within the city, including dwelling houses. The public rate ought in fact to have come first in order, but it is second in the Act of Parliament.

7281. The public rate is upon all rateable property, is it not?—Yes, upon all rateable property within the city.

7282. And you have a special rate called a domestic rate?—Yes, upon all dwelling houses within the city.

7283. Now will you give us the amount, first, of the public rate which is applicable to all rateable property, and, secondly, the domestic rate?—The public rate is and has been for many years past 3*d.* in the pound, and the domestic rate is 9*d.* in the pound. It is upon the assessable value of the property in both cases, so that the 9*d.* and the 3*d.* together might be said to represent something like 10½*d.* in the pound on the rateable value, one-sixth taken off being the gross rental in order to obtain the rateable value.

7284. On the rateable value it is 1*s.*?—Yes on the rateable value it is 1*s.*, but on the gross rental, which is the usual mode of obtaining the domestic rate or rental for the supply of water, it would represent 10½*d.*

7285. But it would not be 1*s.* upon all the property in Manchester?—No.

7286. The domestic rate applies simply to dwelling houses, and you have a 3*d.* public rate which does not apply to dwelling houses?—Exactly, the 3*d.* in the pound is payable by all property; of course for that 3*d.* in the pound it will be understood no water is supplied; they simply pay 3*d.* in the pound as a contribution for the advantages which are secured to the whole community as well as for their protection in case of fire, for cleansing streets, flushing sewers, and in any other way. For the advantages, which one can easily understand are secured by an abundant supply of water, property pays that 3*d.* in the pound.

7287. Threepence in the pound is in fact what may be called the borough rate, for the supply of water for municipal purposes, for extinguishing fires, and cleansing streets, and so on?—Yes, and the general benefit in fact which is secured to the district by providing an ample supply of water.

7288. Then the 9*d.* rate on domestic dwellings is in point of fact a rate for the consumption of water?—For the domestic supply.

7289. And the rateable property would indicate the average amount of water consumed, whether you have a rate of 9*d.* in the pound upon 100*l.* rateable property, or 9*d.* in the pound upon 50*l.* rateable property?—Yes.

7290. It is assumed that a 50*l.* house would use half the quantity of water?—They pay half; probably they might consume a great deal more, but that is how the amount payable is ascertained.

7291. Can you tell us the result, first, of the public rate?—I have an estimate for the last year. On the one side we have the estimated expenditure which together amounts to 120,858*l.* 11*s.* 2*d.* That was the estimated expenditure, including as the main item the interest upon our borrowed capital, which is 74,762*l.* 18*s.* 3*d.*, the borrowed capital at the present time being 1,770,477*l.* 10*s.* 5*d.* Our total expenditure in the year is estimated to be 120,858*l.* 11*s.* 2*d.*

7292. That 120,000*l.* a year not only includes interest on the borrowed capital of 1,770,000*l.*, but also all the working expenses?—It does.

7293. Does it include ordinary repairs?—Yes. I wish to state it shortly, but I have got the items; they are very few; there is a sinking fund account, amounting to 12,566*l.*

7294. How do you spend that sinking fund?—In the first instance, by the earlier Acts of Parliament no sinking fund was required. Subsequently, by a clause in the Act of 1854, Lord Redesdale insisted upon our providing a sinking fund, but consented to a moderate sinking fund of 1 per cent. for a number of years, and after 20 years to be increased to 1½ per cent. The corporation desire to extend the repayment over as long a period as possible, for it will be posterity that will get the benefit of this enormous expenditure, and I have always contended that in those great works, which really are for the benefit of posterity quite as much as for the benefit of the present generation, it is only just to spread the expense over the longest possible period, and that to attempt the repayment in 20 years would be a great grievance upon the present ratepayers.

7295. Then this 12,000*l.* a year will be equal to the redemption of that sum at what rate of interest?—The rate of interest upon the whole capital, notwithstanding the times that we have recently passed through, is, I think, equal to about 4 and a fraction per cent. Our rate of interest for a long time was very little over 4 per cent. All the loans falling due during the past year have either been renewed or the amount borrowed on favourable terms, and the average rate of interest upon the present debt, notwithstanding the late monetary panic, does not exceed 4*l.* 3*s.* 4*d.* per cent.

7296. Do you borrow your money on bonds, or how do you raise it?—We have power to borrow it on bonds and mortgages, we have power to raise it upon annuities, and we have power to issue 4 per cent. annuities in perpetuity. We have also power to borrow it on life annuities, and we exercise, as far as we can, all those powers. We have borrowed, I think, 150,000*l.* or 200,000*l.* on perpetual 4 per cent. annuities, and we should be very glad to borrow 1,000,000*l.* if we could upon those terms, so as to have a fixed debt which we could always reduce by the application of our sinking fund, by going into the market if the case arose.

7297. Have you borrowed any money on bonds or mortgages of the rates? Have you power to give the water rate as a security?—Yes, the Act of Parliament gives the whole property of the corporation practically as security for the money that is borrowed.

7298. Then you borrow under the seal of the corporation proper?—Yes.

7299. And not of the water company?—No, certainly not.

7300. Have you any bonds that you issue which are transferable?—Not except in the ordinary way by assignment; it is in the ordinary way in mortgages as well as in annuities.

7301. I suppose you have not many such bonds out; I draw a distinction between ordinary mortgages upon the rates and bonds which are negociable?—We have no bonds at all; ours are all mortgages of the rates or perpetual annuities, which are issued in a different form, but in the form prescribed by the Act; but both the mortgages and the annuities have to be assigned in the ordinary way when they pass from one person to another.

7302. And registered?—Yes, and registered.

7303. And you have had no difficulty in borrowing your funds under this special Act of Parliament, giving as security not only the rate of the water company, but, I suppose, the rate of the gas company, or the property belonging to the corporation?—Yes, the security is the water rate and the borough rate, and that practically includes all the property which the corporation possess. Generally speaking the mortgage is made upon the borough rate.

7304. Has the corporation used as an auxiliary aid the gas profits?—We did for a certain limited period.

7305. I mean the property of the gas company which you have power to rate, and the profits which would arise from the manufacture of gas?—Many years ago. We got power in one of our Acts to apply, if the corporation thought fit, any amount not ex-

J. Heron, Esq.
2 April 1868.

ceeding one moiety of the gas profits in reduction and in aid of the expenses of the waterworks department. I must explain that the gasworks belong to the inhabitants of Manchester, to the ratepayers, and always did, and the gas profits are applicable, under the Act of Parliament, to carry out improvements within and for the benefit of the inhabitants generally of the city.

7306. Would the establishment of waterworks be deemed an improvement under the Act?—It was considered that they would not have been so applicable under the Act without the authority of Parliament, because no doubt the expression in our Act of Parliament referred to physical improvements, that is to say, alterations in streets and other improvements of that kind; but the corporation felt that the improvement which they were going to secure to the city by obtaining an abundant supply of water was really the most valuable improvement that could be suggested, and therefore they applied to Parliament for power to apply, if the corporation thought fit, not exceeding a moiety of the gas profits, in aid of the annual expenses of the waterworks department for 10 years, and for 10 years that application continued; it then ceased, and it has ceased for some years past.

7307. What was that moiety in amount?—It varied from 15,000*l.* to 20,000*l.* and 25,000*l.* a year. Our gas profits I may say, in round numbers, are something like 50,000*l.* to 60,000*l.* a year.

7308. At what rate per 1,000?—I think it is 3*s.* 2*d.* down to 2*s.* 9*d.* per 1,000, according to the quantity that is consumed. It is very low. It is about, I think, the lowest price that is charged. I am not sure whether the Liverpool price is lower.

7309. Are you making it from Newcastle coal?—No, it is chiefly from Cannel coal; we mix other coal with it to a slight extent.

7310. Is it so that you are selling Cannel coal gas for 3*s.* 2*d.* per 1,000?—I think so. It is not solely Cannel coal, but it is Cannel coal mixed with other coal, but, practically, it is called Cannel coal gas.

7311. But it is not pure Cannel coal gas?—No, it is made from Cannel, mixed with other qualities of coal.

7312. You determined at all events to apply a moiety of the gas profits in that way, and Parliament sanctioned the determination, and you did act upon it for 10 years?—Yes, and it has ceased now.

7313. Then, as I understand, the corporation, finding the condition of things in 1845 to be, first, a deficient supply, and, secondly, impure quality, you undertook to supply yourselves with water, and you borrowed money for the purpose of forming works and securing a gathering ground, which has up to this period supplied the town of Manchester with water?—Yes; we commenced and are still carrying out to a certain extent and perfecting the scheme for which powers were then obtained.

7314. I suppose it would have been utterly impossible for anything like the scheme which you have carried out to have been carried out by private persons, and it could only have succeeded by being in the hands of the corporation?—I feel perfectly satisfied that we should never have had such a scheme carried out unless we had undertaken to do it ourselves. We had been for 30 or 40 years in the hands of the water company, and had only been going from bad to worse. Every attempt which they made, and they made several, in Parliament to get power to carry out other schemes failed, and the corporation felt at last that unless they did it for themselves the work would never be carried out. Besides, the expenditure which we undertook was such an expenditure that it is quite certain no private company would ever have dreamt of encountering; nor was it one which they would have been justified in undertaking. A private company could not have acquired the money. If it had asked Parliament they would not have granted them the powers that we obtained; and it is only by the exercise of those powers that we have been enabled to incur such an expenditure, and to supply, as I think I can show you we do supply, water at a very low price to the inhabitants of the city.

7315. I suppose that a company would have been incompetent to carry out the special schemes which you have had in operation in Manchester, that is to say, the levying of a domestic rate and of a lower rate for public or town purposes, unless the power of supply were in the hands of the municipal authorities?—Certainly. I do not suppose such powers would ever be granted.

7316. You are of opinion, are you not, that the supply of water and of gas to any large town should be in the hands of the municipal authorities?—I think the experience that we have had in Manchester has shown to us most clearly that the advantages are very great indeed of the supply being in the hands of the corporation. I could also give you facts in connexion with Liverpool and Manchester, and other places, where the charge to the low class of houses is really extraordinarily low consequent upon the powers which the corporations have obtained.

7317. Are you now supplying water, not only more abundantly, but of a much purer quality, to the inhabitants of Manchester at a less cost than that at which they obtained their supply prior to 1845?—At a very much less cost, and we are giving them an unlimited supply of, as we have always thought, as pure water as is obtainable.

7318. Does that reduction in cost arise from your mode of spreading the burden of supply over all the rateable property as compared with the charge made by a private water company on domestic dwellings only?—In the first place the public rate goes necessarily in reduction of the charge that is to be made for the domestic supply within the city. That is the first important item, and which is obtained by the power which we possess to rate all property within the city. In the second place, no doubt, as the question suggests, we can rate all dwelling houses, whether they take the water or not, (but they do take it, every house within the city takes it,) and this power diminishes considerably the amount which would otherwise have to be charged if you were only supplying, say half or two-thirds or three-fourths of the houses; the cost is the same, the water is there, the water has been obtained, and it costs no more to supply the whole, assuming that we have got the water, which is the fact, than it would to supply three-fourths or one-half of the dwelling-houses.

7318*a*. Was the price at which you should take the grounds and works of the existing company fixed in the Act of Parliament, or was that a matter which you obtained under the Lands Clauses Act?—No, the corporation dealt liberally with the old company. They had spent an enormous amount very unwisely and very unprofitably, but the corporation determined, when it was resolved to undertake the supply of water, to arrange with the old company the price which should be paid for their works. In 1846 or 1847, when we went to Parliament and obtained the Act, we fixed the price which should be paid when we took possession of their property, and we arranged to take possession of their property in 1851. I think the amount that we paid was something like 530,000*l.*

7319. Did you transfer the proprietors from the company to the corporation, or did you borrow independently a sufficient sum to pay off all the shareholders of the old company?—We borrowed the amount which was necessary, and paid the sum in gross which was agreed with the directors and they distributed it amongst their shareholders; and under our Act of Parliament there were clauses for the extinction, in fact, of the company.

7320. Then you utilized their distributing power in the city, and extended it from time to time as matters might require?—Yes, we made use of their pipes and system of distribution to the extent that we could make it available for our works, and we obtained an entirely distinct source of supply, and gave up altogether the water upon which the city had been previously dependent, considering that it was quite

unfit for distribution, and we filled the Gorton reservoirs from our storage reservoirs in the Longdendale Valley.

7321. In seeking for a fresh gathering ground for the supply of the town of Manchester, how did you arrange with the owners of property to keep the water free from that which might contaminate the source of your supply; what was the cost to the corporation for securing and maintaining that gathering ground free from objection?—The small plan which is before you (*see Appendix W.*) will show, on a small scale, our gathering district. We in fact have purchased the whole of the property above the weir which is placed in the river where the quantity of water which we have to send down daily for the supply of the mills passes. There is no drainage into the river above that point; there are no works; there is no source of pollution above that point. I think there is only one set of works existing which we are now purchasing, which are bleaching works, and when we have purchased such works, there will not be any works of any kind within the area of our gathering ground.

7322. What security have you against the erection of works that will contaminate that area?—I fancy the best security is the nature of the ground. It is a mountainous district where there are no dwellings scarcely, or very few; there are scarcely any at all to be seen.

7323. I mean, have you any statutory powers to prevent the erection of works, the opening of lead mines, or any other manufacturing operations that would pollute the water that you gather into your reservoirs?—We have no special powers to prevent any works being established; but there is no chance of any works of any kind being established within our district.

7324. Do I understand you to say that if such an instance should arise in the district you have no power to buy them off?—I do not know that we should really have any such power.

7325. Supposing that the owner of a part of that area chooses to erect a manufactory, the result of which would pollute the water which you are taking into your reservoirs for the purpose of supplying the town of Manchester, have you any power to prevent it by applying for an injunction to restrain him, or must you, finding he is about to erect such a nuisance, buy him out?—There is no doubt that we should have power by injunction to restrain anyone from polluting our source of supply, if such a case did arise; but the fact is that every drop of water nearly that is to be obtained within the district belongs to the corporation, and the land, too, which could be used for works belongs to the corporation. Our reservoirs fill up the valley for something like five or six miles, and on each side are the hills going up somewhat precipitously, forming the gathering ground to the river. There certainly is some meadow and pasture land still left within the valley, belonging either to the Duke of Norfolk, that is, Lord Edward Howard, or to Mr. Tollemache; for, fortunately, we had only to deal with two owners in purchasing the property required for our works. It so happens that one owned the whole of the property on one side of the river, and the other owned the whole of the property on the other side.

7326. But you did not purchase the whole area which you have coloured on the map as your gathering ground?—No, certainly not.

7327. How do you deal with the rights of A. B., whose rights Parliament has not dealt with, and which, therefore, remain intact, supposing he chooses to erect anything on the ground which would interfere with your supply?—We should only have the ordinary power which belongs to all waterworks companies to prevent anybody who cannot show that he had been doing it from a certain time, so as to have obtained the right carrying on any business which would have the effect of polluting our water.

7328. Are you not restricting the rights of property; you have never paid a penny for this right?—I think not; but the fact is that it is a question which I have never had to consider, and there are no such parties in our district. It is not like some districts where you might meet every few yards with property that might appear to be available for business purposes of some kind or other. We have no such sites within the district, and no nuisance of the kind has occurred. There was one property within the district, which was an old printworks, which had not been used for many years, which they said they had once used for dyeworks. It had been unoccupied for very many years; no tenant could be got to take it, for it was too far removed from the markets, and there were many other objections to it as a trading place, but we bought that place. We agreed to buy the property, in order to get rid of the possible chance of somebody taking it merely to try to screw something out of the corporation by saying that they had a right to carry on dyeworks. That is the only place of the kind that I know of.

7329. Have you power under your Act to prevent a man utilizing his freehold as he pleases, supposing that utilization should at all interfere with the quality of your water?—No man can go and establish works in that district to foul our water. We should have power to restrain him by an injunction if he were to attempt to carry on any business, the effect of which would be to render our water impure or unfit for the purposes for which we collect it.

7330. With regard to the supply of Manchester prior to 1845, was it on the intermittent system?—Yes, it was very intermittent and very irregular.

7331. When you established your works did you continue that system, or have you a constant supply in Manchester under high pressure?—From the time that we took possession of the works we have established the system of constant supply. I fancy there was some little delay, perhaps, in carrying it out thoroughly after we took possession, and partly, though not, perhaps, to any great extent, that might have been the result of the general arrrangements which were being carried out for introducing the constant system instead of the intermittent system; but, as a rule, I may say that we have never had the supply upon any other system than the constant system.

7332. Can you tell us what were the difficulties in the first instance in adopting the system of constant supply as compared with the previous system; you purchased the distributing plant of the old company, did you not?—Yes. I am not aware of any difficulties of any kind having occurred.

7333. Did you turn on your water under a given pressure to enable you to extinguish all fires without any alteration being made in the internal fittings of the consumers?—I really can hardly say to what extent some alterations may have been required, but certainly I am not aware, and I have never heard of there having been any difficulties. I do not know that the pipes that were in existence were not found sufficiently strong for the additional pressure they had to bear; and of course, as far as regards the internal arrangements, they would be very simple. I do not know that they would or did require any special change.

7334. Did the result of your new system abolish water cisterns?—There is no doubt that it rendered them unnecessary. I should say that in the small class houses cisterns do not exist; it would be a totally useless and unnecessary expense to go to. I know, as a matter of fact, that they are not put into the small houses.

7335. Do you group a number of houses to one supply, or do you give an independent supply to each house of the poor, for example?—Generally speaking, there is an independent supply to each house. We have 66,907 houses supplied within the city, whilst of 10*l.* rateable value and under, there are 52,737.

7336. (*Sir B. Phillips.*) Is 10*l.* the assessable value?—Yes. We have a certain number of standpipes still left; there are 2,078 stand-pipes, supplying 21,235 tenements, which are chiefly in courts or small streets; they are stand-pipes where the water is constantly on with proper arrangements, so as not

J Heron, Esq.

2 April 1868.

to have unnecessary waste, and to which the tenants of some particular houses have access. I may say that we do not allow any houses to be supplied by means of stand-pipes now, and have not done so for many years; that is to say, no new stand-pipes are erected. For many years the corporation have insisted upon the supply being in each house independently, and the stand-pipes have been diminishing gradually. We shall be very glad to do away with them altogether; they have diminished to the extent of 500 within the last two years.

7337. (*Chairman.*) That is to say, you place a pipe in a house in a convenient spot with a tap?—Yes, and they take the water as they like; it is always on, night and day.

7338. Are those pipes associated with waterclosets, or how do they arrange that?—That is a question which I cannot exactly describe. I am happy to say that in Manchester, as a rule, we have no waterclosets in the small houses.

7339. Have you cesspools?—No, we have no cesspools; the houses have got a privy and a dry ashpit.

7340. Those are emptied from time to time and deodorized by ashes?—Yes, the town performs that duty at a cost of something like 10,000*l.* a year. The privies and ashpits throughout the whole city are emptied by the corporation, and we get rid of the contents as well as we can by sending it into the country, into Lincolnshire or Yorkshire and other places, almost giving it away; but still we do get rid of it, and we get some 8,000*l.* or 9,000*l.* a year towards the expense of nearly 20,000*l.*, which we incur in the operation.

7341. Have you observed by any report from the medical officer, or from your own observation, any improvement in the general health of the inhabitants since the introduction of this pure and abundant water supply, and the adoption of this constant system as compared with the intermittent system, and abolishing all the old mode of storing?—I cannot say that I have observed the change, and of course it is too notorious that the death-rate in Manchester is certainly not at all satisfactory at the present time. In Manchester and in Liverpool, where the supply of water is most abundant, whatever the cause may be, the death-rate is certainly rather high than otherwise, as compared with what it is in many other places. Therefore, as far as that would be a criterion, we cannot boast that there has been any very great improvement. No doubt there must be some.

7342. That may be due, may it not, to imperfect drainage?—Of course it must be due to other causes, because that the benefits from the supply of water have been very great cannot be doubted.

7343. I suppose that for manufacturing purposes the supply of this soft water is a great benefit?—It is an enormous benefit. There are many cases where printers and others pay a very large sum per annum to the corporation for the water in preference to water which might be obtained at a less cost probably, but which is not of the same quality. The income which we derive from the water sold for trading purposes is very large, and it is by that income alone that we are enabled to supply the water at the low price we do for domestic purposes within the city. Perhaps I might just as well state what that is, for I did not finish the information that I was giving with regard to the effect of the two rates. I showed only that the total cost was 120,000*l.* per annum in round numbers. The estimated receipt for trading purposes and for water supplied for domestic purposes beyond the limits of the city is 69,812*l.* a year.

7344. (*Sir B. Phillips.*) Is that over and above the 120,000*l.*?—No; I am giving you the credits. The debit side is 120,000*l.* a year, that is the cost, including everything, in the year for working the waterworks establishment. On the other side we have to estimate our receipts in order to ascertain for what amount we must make the rates; and the receipts on the other side are 76,312*l.*, with sundry other receipts amounting to 3,000*l.*, that being for trade and domestic purposes without the city, making altogether 79,312*l.* Then we have to raise the balance by means of our two rates, one of which at the rate of 3*d.* in the pound on the assessment of 1,438,000*l.* 16*s.*, less one per cent. for loss in collection, it is estimated will raise about 17,797*l.*, and the domestic rate of 9*d.* in the pound on an assessment of 638,508*l.* 10*s.*, it is estimated will raise 21,762*l.*, making together 39,559*l.* 7*s.* 10*d.*, or a total of 120,858*l.* 11*s.* 2*d.*, less 1,987*l.*, which was the balance which we do not provide for in that estimate, but which amount we know, from the experience of past years, will be more than provided by the increased amount received for domestic and trading purposes during the year.

7345. (*Chairman.*) Is your rate pretty uniform from year to year?—Yes; it has remained the same for many years, and I think myself that the probability is that it will continue the same for many years to come, because if we have a balance, which we have had in some years, beyond our expenditure in the receipts, we do not carry it to the credit of the next year, but we pay it in addition to the amount which we have raised expressly towards the sinking fund. Our sinking fund is small, and if we could raise three times the amount, probably in the shape of the sinking fund, without raising or altering the present rates, we should do so, because it is felt that the rate at which we now supply the water is quite as low as anybody has a right to expect.

7346. Then anything plus your expenditure is added to the sinking fund?—Yes, thus reducing the debt; and we always begin the next year without any credit.

7347. (*Colonel Harness.*) How do you fix the charge for water supplied outside the city?—It is fixed by the Act of Parliament, and it is five per cent. upon the rental; that is to say, it cannot exceed five per cent. upon the rental. As a rule it is five per cent. upon the rental of the property to which it is supplied, with the usual limitation that in no case is it to exceed 10*l.* I think it is that as the rule; and then there are the ordinary powers for charging for baths, stabling, and the ordinary powers given to a waterworks company. I may state that the area over which Manchester supplies water is something like 80 square miles. The whole district is in fact dependent upon Manchester for its supply of water.

7348. (*Chairman.*) When you speak of Manchester, do you include Salford and those other places?—Yes, we supply Salford. The whole district, including Salford, is dependent upon Manchester for the supply. We go all round the city. We supply three companies entirely. The corporation of Salford is supplied entirely by Manchester in consideration of an annual charge. We supply Staley Bridge; they are making works for themselves. But we supply the North Cheshire Company, which goes to Bowdon, Stretford, and that district. We supply Tyldesley, which is beyond Manchester five or six miles on the other side towards Worsley, and all the districts round it. We also supply the Dukinfield Company, and we supply Stockport with a portion of their water, and Hyde, besides all the intermediate district.

7349. In the city of Manchester have you not a number of hydrants in different parts for the purpose of suppressing fire in the town?—Yes, the fire arrangements, I believe, are as complete almost as could be desired.

7350. What height can you throw your water from those hydrants?—The height varies; but I may state that the use of engines is a thing not known scarcely, and it is never required to use engines in case of fire.

7351. Are you able to throw your water to the top of those very high manufactories?—Yes, easily; without any difficulty we can throw it over the highest buildings that exist. The corporation not very long ago went to a very large expense in order to secure a better pressure, not only for the extinction of fires, but also for the supply of some of the highest districts. If you look at the little map you will see Godley is shown as one of our reservoirs; it is the first of our service reservoirs on the Manchester side after

oming through the hill, and at a much higher level han Denton, from which the supply had been previously obtained. The corporation expended something like 100,000*l.* to bring a new main from that Godley reservoir into Manchester, by means of which we are able to supply the districts beyond Manchester which I have already referred to, which are at a high level, and also to supply the whole of the high districts within the city itself and the immediate neighbourhood with all the pressure that is desired. This pressure can be obtained throughout the whole city in case of fire.

7352. Do I understand that this new reservoir to which you refer simply gives you a greater head of water and increases your pressure; but is that pressure constantly on in Manchester, or have you some mechanical means of turning it on in case of fire occurring in the district?—It is constantly on in some portions of the district; but there are districts where the Denton pressure is on, and also there are other districts where the Gorton pressure is on ordinarily, but there is no difficulty in case of fire in turning on the largest pressure that we have. We can turn the Godley pressure into those districts by mechanical arrangements which exist, so that in case of fire the highest pressure may, if it is necessary, be obtained. I do not know whether it has been stated before, but the result of the operations of our fire brigade have been most extraordinary. I have here a statement of the annual number of fires that have taken place for many years, the amount of property that has been destroyed, and the amount of property at risk that has been saved; and it is extraordinary how the per-centage of property saved has increased during the last few years and the per-centage of property destroyed decreased.

7353. You mean since you increased your pressure?—Yes, since we got a better pressure. Last year's return shows that 97·5 per cent. of the property at risk was saved, there having been lost only 25,605*l.*, whereas there was 1,019,779*l.* property at risk; and I see that in the previous year there was 90 per cent. saved. In 1866, the year before that, there was 96·7 saved, 96·8 the year before that, 94 the year before that, and so on for many years back; and before that there has been actually only 59 per cent. saved, and 78, 80, 85, and 66, but I believe that the operations of the fire brigade have been in every respect extraordinarily satisfactory to all parties concerned.

7354. Before going into another part of the question, let me ask you whether the corporation annually appoint a committee for the purpose of managing its water supply and gas, or separately?—The waterworks committee is a distinct committee.

7355. (*Sir B. Phillips.*) You mentioned that you had a general rate and a domestic rate. Will you be good enough to tell us in what way manufacturers are supplied by you, is it by an independent rate, or is it by an arrangement?—Manufacturers are supplied at such prices as may be arranged between them and the corporation; but the fact is that the corporation have fixed the rate of charge, beginning at 1,000 gallons and going up to 3,000,000 gallons per quarter, which is published. I cannot state exactly what the price is, but I think it begins at something like 2*s.* per 1,000 gallons, and if they take 3,000,000 gallons quarterly, I know the price is cut down to nearly 3*d.* per 1,000 gallons.

7356. Can you tell us what amount the corporation derive annually from the supply of water for manufacturing purposes?—Yes. I find that the trade rentals within the limits of the city, that is, for water supplied for trade purposes only within the limits of the city, were 35,647*l.*, and beyond the limits of the city, 10,734*l.*, that is, 45,000*l.* a year and upwards. The domestic rentals beyond the city were about 23,430*l.*; so that it is 45,000*l.* and upwards that we receive for water sold for trading purposes.

7357. That amount is produced, is it not, by arrangement with the manufacturers?—That is so.

7358. You have told us that there are something over 50,000 houses at Manchester rated at 10*l.* per house and under; you have necessarily some very small tenements?—Very.

7359. Speaking of small houses, can you tell us what number of houses you have of 5*l.* and under per annum?—The number of assessments at 5*l.* and under is 4,656, and the value is 23,280*l.*

7360. Do the corporation collect the water rate from each of those houses separately, or from the proprietors or landlords?—From the landlords. The landlords are liable, by a special clause, for all property in Manchester let to weekly tenants, whatever the rent may be; but they are liable for all at 10*l.* and under, quite independently of that additional power which we obtained. We found that it was so desirable that where there were weekly tenants constantly changing, the landlord should be made liable, that we got that power in one of our Acts.

7361. Is that merely for weekly tenants?—The landlords are liable under all circumstances for 10*l.* and under, but they are liable also in all cases where the property is let to weekly tenants.

7362. Are we to understand that if a house be let in Manchester, and is rated at 7*l.*, 8*l.*, or 9*l.* per annum, and the tenant in possession refuses to pay the water rate, the corporation can oblige the landlord to pay it?—We should not go to the tenant; we go to the landlord. We have nothing to do with the tenant; we are compounders, that is to say, we go to the landlords. If I were to refer to the clause I could tell you what the amount is that the landlords are entitled to have in reduction, but we can go to the landlord, who is liable; he makes his own agreement with his tenant. We have nothing to do with the tenant at all.

7363. I think I understood you to say that each of those houses is supplied with pipes brought into the house?—To the extent to which I have already stated.

7364. You stated that there were something like 2,000 stand-pipes which had been reduced 500. In all the recently built houses you introduce pipes and taps, do you not?—Yes, there are 31,502 houses which are supplied internally, and externally, by means of stand-pipes, 21,235.

7365. How is the water stored that supplies those pipes?—There is no storage in any case, it is always on. If it is a stand-pipe they have nothing to do but turn the tap, or whatever it may be, and there is the water.

7366. That I suppose comes from the reservoir in the immediate neighbourhood?—No, it comes from the pipes some miles from any reservoir; it supplies the stand-pipes as it supplies the houses, from pipes running through the streets.

7367. (*Colonel Harness.*) Has it ever occurred that the district was without water on account of repairs being done to the pipes in the streets?—Occasionally of course that does occur. I know in my own house, which is in Broughton, the other day for some hours we were without water, but then in the course of a few hours it was on again. That must necessarily arise occasionally; if there is the bursting of a pipe no possible means can prevent the whole district being without water for a limited period.

7368. Except they use the cistern?—Precisely so. A cistern might be useful under such circumstances.

7369. (*Sir B. Phillips.*) For a limited period the whole district would be without supply until the pipe was repaired?—It might; of course the district might be smaller or larger, but I have never heard of any inconvenience arising from it.

7370. (*Mr. Harrison.*) Many of your large houses have cisterns, have they not?—Yes, I scarcely know of any large houses that do not have cisterns to catch the rainwater.

7371. (*Chairman.*) Have you calculated at all the quantity of water per head of the population?—Yes; the estimated consumption per head is 13½ to 14 gallons daily.

7372. Is that apart from the borough consumption, as you may call it, and from the manufacturing consumption?—It is apart from the manufacturing, as that estimated consumption is for domestic purposes only.

J. Heron, Esq.
2 April 1868.

7373. Taking the whole supply of Manchester, both for municipal and manufacturing purposes, and for domestic supply, what is the supply, as spread over the inhabitants, per head?—The total quantity of water distributed now is about 14,000,000 gallons daily. The population is about 650,000, and the estimate for consumption for domestic purposes is 13½ gallons daily, making about 9,500,000 gallons; there is something like 4,500,000, say 5,000,000 gallons supplied for trading purposes, and that would include sanitary purposes.

7374. Taking 13,000,000 gallons for domestic purposes, and then adding the 4,000,000 to 5,000,000 gallons for other purposes, spreading it over the whole that would give the average consumption, per head, at about 22 gallons?—I have no doubt it would be nearly that. I have a statement which I thought might be interesting, showing what the rates are in other places: In Manchester we have the 3*d.* public rate and the 9*d.* domestic rate; in Glasgow they have 1*d.* public rate, and their domestic rate, which is compulsory, is 1*s.*; in Liverpool they have a fixed and unvarying 6*d.* public rate, by Act of Parliament, 3*d.* of which public rate is payable by the owner and 3*d.* is payable by the tenant. The domestic rate, which is not compulsory, is only about 6¾*d.* in Liverpool.

7375. Liverpool supplies itself in the same way as Manchester, does it not?—They have not a compulsory domestic rate. It is voluntary as far as the domestic rate is concerned.

7376. But the waterworks are in the hands of the corporation?—Yes, they are; and in Glasgow they are in the hands of the corporation also, and there it is compulsory, both the public and domestic rate. In Bristol they have no public rate; but in Dublin they have adopted the same principle as in Manchester. They have a 3*d.* public rate, and they have a 1*s.* domestic rate; but there their charge is much higher than Manchester. There is no place but Liverpool that I can see which supplies water for the small class houses as cheaply as we do in Manchester; but in Liverpool the price they charge is extraordinarily low, for they begin at 1*s.* 8*d.* a year for the small houses. I will hand in to the Commission a comparative statement of the charges between Manchester and other places. In the Act of Parliament we got power to charge for all premises if supplied externally, that is to say, by means of stand-pipes, 4*s.* a year—not to be called upon to supply for less than 4*s.* a year; and for all premises supplied internally 5*s.* a year; and that is the rate charged for nearly all houses, we may say, under 10*l.*

The witness delivered in the following table:—

MANCHESTER CORPORATION WATERWORKS.

Charges by various Companies for Water—Public and Domestic.

Name of Town.	Corporation or Company.	Public Rate in the £.	Domestic Rate in the £.	Compulsory or by Agreement.	——
Manchester	Corporation	3*d.*	9*d.*	Compulsory.	
Glasgow	Do.	1*d.*	1*s.*	Do.	
Liverpool	Do.	6*d.* See note A.	6¾*d.* See note B	Compulsory on 10*l.* and under.	
Dublin	Do.	3*d.*	1*s.*	Compulsory.	
Bristol	Company	None	5 °/₀ to 25*l.*, then sliding scale to 2½ °/₀.	By agreement.	
New River Company, London.	Do.	None	Under 200*l.* 4 °/₀ on the annual value, equal to 9¾*d.* in the £; above 200*l.* 3 °/₀ on the annual value, equal to 7½*d.*	Do.	
Birmingham	Do.	None	To 5*l.* per annum 6*s.* per annum from 5*l.* to 7*l.* 10*s.* 8*s.* do. 7*l.* 10*s.* „ 10*l.* 10*s.* 4*d.* do. 10*l.* 0*s.* „ 12*l.* 10*s.* 16*s.* 9*d.* do. 12*l.* 10*s.* „ 15*l.* 24*s.* do. 15*l.* „ 17*l.* 10*s.* 31*s.* do. 17*l.* 10*s.* „ 20*l.* 38*s.* do.	Do.	Houses 10*l.* 8*s.* and above may be farmed by landlord, and 20 °/₀ allowed for a term of years for composition or empties.

A.

The Liverpool Corporation charge the compulsory public rate half to owner and half to tenant as per 25° & 26° Vict., cap. 107, sec. 27, (Liverpool Corporation Waterworks Act, 1862), but in case of cottages let at 10*l.* and under the owner is made liable to the whole rate, one half of which he may charge to the tenant at rent, but the assessment is not to be increased in consequence of such additional charge, and 25 per cent. is to be allowed as composition.—*See sec.* 46.

B.

The domestic rate for property 10*l.* and under is made chargeable to the owner under the provisions of 10 Vict., cap. 17, sec. 72 (the Waterworks Clauses Act, 1847); 25 per cent. also being allowed to the owner as composition.

7377. About 2½ per cent.?—Yes.

7378. (*Mr. Harrison.*) What surplus do you suppose you have beyond your present delivery within the gathering ground that you have?—I am not quite certain what would be the surplus at the present moment; but we have a large surplus, and when the works are completed which we have in progress, and which will be completed before the additional quantity of water will be required, we shall have, as far as we can judge, at least 25,000,000 gallons a day, after providing 14,000,000 gallons a day which goes down the river for the supply of the mills.

7379. Have you no fear at all of any deficiency of supply for Manchester, or for the district that you supply in addition to it?—Certainly not.

7380. You do supply towns at a distance as great as 10 miles, do you not; or what is the most distant place?—Directly we do not go quite so far. Bowden is perhaps the most distant place that is supplied from the Manchester Waterworks; but that is through the intervention of another company, the North Cheshire Waterworks Company; but it is our water that supplies them. It also goes to Alderley, which is supplied through the Stockport Waterworks Company with our water, and is 14 or 15 miles from Manchester.

7381. Would it be a good principle for a company or corporation situated as you are, and being of necessity obliged to undertake very extensive works to supply not only your own town, but an extensive district in connexion with it, say within the same watershed as yourselves?—I think it is decidedly an advantage for any company, situated as we are, to have, provided they have got the water, as large an additional district to supply as possible. The coporation is able to supply a large district beyond the limits of the city, and it is by means of the income which we thereby obtain that we are able to pay our expenses and to keep down our rates within the city.

7382. Have you ever turned your attention to the same principle being carried out upon a much more extended scale than it is at present with regard to other districts in England?—No, I cannot say that I have ever considered the question from that point of view. One can very well see that what has proved advantageous in Manchester in its working would, if the same system were carried out in any other district, have the same result.

7383. Do not you find within your own district that there are many towns not of sufficient magnitude to justify their going to any large expense to get the

best water, who can now be supplied through you much more economically than they otherwise could have been?—No doubt; and I believe that if the corporation of Manchester had not carried out those large works which enable them to supply those small districts, those districts would have been without water. They never could have encountered the expense as well as the difficulty which would have been necessary in order to obtain it.

7384. Does your experience lead you to the conclusion that works carried on by a corporate body are economically done?—I do not see why they should not be carried out quite as economically as under any other system. Certainly, if the duties devolving upon those to whom the works belong are properly performed, one would expect there would be greater regard to economy than under any other arrangement.

7385. Do you find that the gentlemen whom you may appoint as special members of that committee find time to devote to it?—They do certainly give their time in a manner which often surprises me, and I think they sometimes pay more regard to economy in carrying out the works than they would do probably if it was their own business. As far as my experience goes I can certainly bear strong testimony to the time and attention which the members of the corporation pay upon those important committees, both the gas committee and the waterworks committee.

7386. With regard to the economy in the consumption of water or otherwise resulting from constant supply, can you give any opinion upon that subject?—I do not think that my opinion would be of much value. I do not think I can speak with anything like authority. We have fortunately had no experience except of the one system, and we cannot understand at all how any other system can for one instant be put in competition with it. Our impression is that it is decidedly more economical to have a constant supply than an intermittent, and that there is less lost in many ways which I have no doubt will suggest themselves to you.

7387. What powers of supervision have you over the different houses and tenements?—We have most ample powers of every kind both for inspection, to see that the fittings of every description are of a satisfactory character, and also to provide what those fittings shall be. The corporation have the most complete powers. We had to apply several times to Parliament to get amended powers, which we have found necessary. We certainly are not working under the ordinary Waterworks Clauses Act. We have many provisions which I do not think are to be found in that Act of Parliament. We have most ample powers with reference to fittings, and also for the purpose of inspection.

7388. Would not a similar power be a matter of absolute necessity in the case of London being put upon the constant supply system?—I should think it absolutely necessary in any case. I think it is quite right that whoever is supplying water, whether it is a corporation or a company, should have ample power to see that the water is not being improperly wasted.

7389. Do you find any complaints from owners of property of such supervision being at all inquisitorial?—Not at all; I never heard a complaint of the kind, and we have found it to be most necessary; for when we increased the pressure in the way which I have mentioned to the Commission we found our consumption was very rapidly increasing, and that there must be some cause for it, and an extra inspection was immediately ordered, and we found that the fact was that the pressure of the water on the ball taps, the handle of which was not of very strong metal, but rather a pliable metal, had twisted it, so that the ball tap was no longer operating in any way, and that in scores of cases there was a constant running to waste of our water. When that was discovered the corporation took means instantly for supplying ball taps of a different description, which would be strong enough to bear this pressure.

7390. Are the powers which you possess set forth in the different Acts which you from time to time obtained?—Yes, they are. I intended to have brought a printed copy of all the provisions, but I will undertake to send it to the Commission if it be considered as put in. It is printed separately for the information of everybody. I hand in a printed copy of the clauses referred to.

J. Heron, Esq.

2 April 1868.

MANCHESTER CORPORATION WATERWORKS.

EXTRACTS FOM THE WATERWORKS ACTS (AND THE ACTS INCORPORATED THEREWITH) RELATING TO THE MODE OF SUPPLY, PROTECTION OF THE WATER, &c.

Waterworks Act, 1860; 23 *Vict. Cap.* 93.

Regulations for preventing waste of water supplied by the corporation.

CLAUSE 3. For the purpose of preventing the waste, misuse, or undue consumption or contamination of the water of the corporation, the corporation from time to time may prescribe the size, nature, strength, materials, mode of arrangement, and repair of the pipes, valves, cocks, cisterns, water-closets, and other apparatus to be used; and may interdict any arrangement and the use of any pipes, valves, cocks, cisterns, water-closets, and other apparatus which, in their judgment, may tend to any waste, misuse, undue consumption, or contamination.

Conditions of supply.

4. The corporation shall not be bound to supply any water unless the pipes, cocks, cisterns, water-closets, or other apparatus to be used be made of such size, nature, strength, and materials, and be so arranged and repaired, as the corporation from time to time prescribe or approve; and in the event of any dispute as to whether such pipes, cocks, cisters, water-closets, and other apparatus are of such size, nature, strength, and materials as aforesaid, or have been so arranged and repaired as prescribed and approved by the corporation, such dispute shall be settled by two justices, either of the city of Manchester or the county of Lancaster, in the manner provided by "The Railways Clauses Consolidation Act, 1845," with respect to the recovery of damages not specially provided for, and of penalties, and for the determination of any other matter referred to justices.

Repair of pipes, &c. by the corporation.

5. The corporation may, after twenty-four hours' notice, repair or alter any pipe, valve, cock, cistern, water-closet, or other apparatus, of any person supplied by them with water, so as to prevent any waste of water; and the expenses of the repair or alteration, if well and effectually done, shall be repaid to them by the person on whose credit the water is supplied thereto, and may be recovered by them as damages.

Penalty for waste of water by non-repair of pipes, &c.

6. Every person supplied with water by the corporation who wilfully or negligently suffers any pipe, cock, cistern, water-closet, or other apparatus to be so used as that water supplied to him by the corporation is wasted or misused, so as to allow an undue consumption of the water of the corporation, or to allow the return of foul air or other noisome or impure matter into the pipes belonging to the corporation, or connected with the mains or pipes of the corporation, shall for every such offence forfeit to the corporation a sum not exceeding five pounds.

Particulars of penalties shall be published.

7. The corporation shall, from time to time, publish the short particulars of the several offences for which any penalty is imposed by this Act, or "The Waterworks Clauses Act, 1847," or either of them, or by any byelaw of the corporation affecting other persons than the corporation, their officers or servants, and of the amount of every such penalty; and also the size, nature, and strength of the pipes, cocks, and other apparatus to be used within the district which the corporation are empowered to supply with water; and shall cause such particulars to be painted on a board, or printed upon paper and pasted thereon, and shall cause such board to be hung up or affixed on or in some conspicuous part of the Town Hall at Manchester.

Powers to corporation for ascertaining quantity consumed by meter, and for removing meters.

9. The officers of the corporation may enter any house, building, or lands supplied by the corporation by measure, in order to inspect the meters, instruments, fittings, and works for regulating the supply of water, and for the purpose of ascertaining the quantity of water consumed or supplied, and may from time to time enter any house, building, or lands for the purpose of removing or carrying away any meter, instrument, pipes, fittings, or other works belonging to the corporation; and if any person hinder any such officer from entering and making such inspection, or effecting such removal, every person so offending shall for every such offence forfeit to the corporation a sum not exceeding five pounds; provided always, that, except with the consent of a justice, such power of entry shall not be exercised at any hour not authorized by "The Waterworks Clauses Act, 1847."

J. Heron, Esq.

2 April 1868.

Penalty for affixing tubes to pipes of corporation without their consent.

10. It shall not be lawful for any owner or occupier of any house supplied with water by the corporation, without the consent of the corporation, to affix, or permit or suffer to be affixed to any of the mains or other pipes of the corporation, or to any service-pipe of such owner or occupier, any gutta percha or other tubes or pipes for the purpose of washing the windows or fronts of houses or other buildings, or for watering any gardens or the pavements or roads adjacent to such houses or buildings, and any person who shall act contrary to this enactment shall, for every such offence, forfeit to the corporation any sum not exceeding forty shillings.

Waterworks Act, 1863; 26 & 27 *Vict.*

Provision with respect to the illegal use of water.

Clause 41. And whereas by the act of one thousand eight hundred and forty-seven the corporation are empowered to levy within the city of Manchester, from all occupiers of all dwelling-houses, a rate called the domestic water rate, and are compellable in consideration thereof to supply to such dwelling-houses water for the domestic purposes defined in that Act; and by the same Act the corporation are also empowered to demand and receive from the occupiers, and in some cases from the owners, of dwelling-houses within their limits of supply outside the said city, requiring to be supplied with water for domestic purposes as so defined, the several rents in the said Act mentioned: And whereas the water supplied by the corporation for domestic purposes as so defined, is frequently used by manufacturers, dyers, printers, bleachers, brewers, innkeepers, alehouse keepers, beershop keepers, vintners, and other persons for purposes other than those defined by the said Act as domestic purposes, and no sufficient provision exists for the prevention thereof: therefore in any case in which any person receiving from the corporation a supply of water for domestic purposes shall knowingly use, or permit to be used, any of such water for purposes other than domestic purposes, as defined by the said Act, the corporation may, if they think fit, thenceforth refuse to supply water to such person at and for the rates or rents for domestic supply prescribed by the said Act, and such person shall thenceforth in respect of the same premises be entitled to a supply of water only under the provision of the ninety-sixth section of the said Act.

Penalty on interference with valves, &c., of the corporation.

42. Every person who shall wilfully, carelessly, or without due authority from the corporation, in any way interfere with any valve, pipe, lock, cock, or other apparatus or works of the corporation, or with any meter used for registering the quantity of water supplied by the corporation, shall, without prejudice to any other right or remedy for the protection of the corporation, or the punishment of such offender, be liable to a penalty for every such offence not exceeding five pounds.

Water may be cut off in certain cases.

43. If any person supplied with water by the corporation wrongfully do, or cause or permit to be done, anything in contravention of any of the provisions of the Waterworks Acts, or of the incorporated Acts, or of this Act respectively, or wrongfully fail to do anything which under any of those provisions ought to be done for the prevention of the waste, misuse, undue consumption or contamination of the water of the corporation, the corporation may cut off any of the pipes by or through which water is supplied by them to him or for his use, and may cease to supply him with water so long as the cause of injury remains or is not remedied, and may also recover from him the amount of any loss, damage, or injury sustained by them by or in consequence of any such act or failure by action at law, in any court of competent jurisdiction, including any county court, or other court having cognizance of any cause of action of like amount.

Penalty for waste of water by non-repair of pipes, &c.

44. If any person supplied with water by the corporation shall wrongfully cause or suffer any pipe, valve, cock, cistern, bath, soil-pan, watercloset, or other apparatus or receptacle to be out of repair, or to be so used or contrived as that the water supplied to him by the corporation is or is likely to be wasted, misused, unduly consumed, or contaminated, or as to occasion or allow the return of foul air, or other noisome or impure matter into any pipe belonging to or connected with the pipes of the corporation, such person shall, for every such offence, forfeit to the corporation a sum not exceeding five pounds, and shall forthwith remove, replace, or alter, or permit to be removed, replaced, or altered, any such pipe, valve, cock, cistern, bath, soil-pan, watercloset, or other apparatus or receptacle, to the satisfaction of the corporation or their duly-authorised officer.

Penalty on wrongful use of water.

45. Every person who, not having agreed to be supplied with water by the corporation, shall wrongfully take or use any water from any reservoir, watercourse, conduit, or pipe belonging to the corporation, or from any pipe leading to or from any such reservoir, watercourse, conduit, or pipe, or from any cistern, fountain, or other like place containing water belonging to or supplied by the corporation, shall for every such offence forfeit to the corporation a sum not exceeding five pounds, and every person who, being rightfully entitled to make use of the water of the corporation for any purpose, shall take or use any water from any such reservoir, watercourse, conduit, or pipe, or from any such pipe, cistern, fountain, or other like place for any purpose other than the purpose for which he is so entitled to be supplied, shall for every such offence forfeit to the corporation a sum not exceeding five pounds, and in any of the cases aforesaid the corporation shall be entitled, in addition, to recover from any such person the amount of any loss, damage, or injury sustained by them by or in consequence of any such wrongful acts by action at law, in any court of competent jurisdiction, including any county court or other court having cognizance of any cause of action of like amount.

46. Any person who shall, without the knowledge or consent of the corporation, affix, extend, or enlarge any pipe, or use any other means or device for the purpose of supplying any other person or tenement with water from the works of the corporation, shall forfeit and pay a sum not exceeding five pounds, and a further sum not exceeding forty shillings, for every day during which such offence shall be continued.

Waterworks Clauses Act, 1847; 10 *Vict. Cap.* 17.

Clause 57. The surveyor, or any other person acting under the authority of the undertakers, may, between the hours of nine of the clock in the forenoon and four of the clock in the afternoon, enter into any house or premises supplied with water by virtue of this or the special Act, in order to examine if there be any waste or misuse of such water; and if such surveyor or other person at any such time be refused admittance into such dwelling-house or premises for the purpose aforesaid, or be prevented from making such examination as aforesaid, the undertakers may turn off the water supplied by them from such house or other premises.

58. Every owner or occupier of any tenement supplied with water under this or the special Act, who shall supply to any other person, or wilfully permit him to take any such water from any cistern or pipe in such tenement, unless for the purpose of extinguishing any fire, or unless he be a person supplied with water by the undertakers, and the pipes belonging to him be, without his default, out of repair, shall forfeit to the undertakers, for every such offence, a sum not exceeding five pounds.

59. Every person who, not having agreed to be supplied with water by the undertakers, shall take any water from any reservoir, watercourse, or conduit belonging to the undertakers, or any pipe leading to any such reservoir, watercourse, or conduit, or from any cistern, or other like place containing water belonging to the undertakers, other than such as may have been provided for the gratuitous use of the public, shall forfeit to the undertakers, for every such offence, a sum not exceeding ten pounds.

60. Every person who shall wilfully or carelessly break, injure, or open any lock, cock, valve, pipe, work, or engine belonging to the undertakers, or shall flush or draw off the water from the reservoirs or other works of the undertakers, or shall do any other wilful act whereby such water shall be wasted, shall forfeit to the undertakers, for every such offence, a sum not exceeding five pounds.

7391. Had you an opposition originally to the power of levying an unlimited rate?—We had no opposition at all. It may have been that it was scarcely understood. It is quite certain that no such power would again be granted by Parliament as we have in this Act. When Glasgow proposed to follow our example there was an opposition, and they were limited to a public rate of, I think, not more than a penny in the pound. We can levy any amount of public rate we please; there is no limit either on the public or the domestic rate, nor is there anything in the Act of Parliament to fix the proportions of the two rates. At the same time the corporation have tried to fix it upon a principle which is satisfactory to the inhabitants, and I may say, from my own knowledge and experience, that I believe there is no rate paid in Manchester so willingly and so cheerfully as the 3*d.* public rate, for which a great number of the largest ratepayers get nothing except the advantage of improving the district.

7392. (*Chairman.*) They get protection from fire; do they not?—Yes, but they get that without it in many other places; they always have protection against fire wherever waterworks exist; they have

right to have water without charge in case of fire. In Manchester of course they have that advantage amongst others, but still the public rate was a new charge.

7393. (*Mr. Harrison.*) Do you find that the fact of your having that unlimited power of rating has enabled you to borrow your money more cheaply than you otherwise would have done?—That has occasionally been made use of as an argument to show the satisfactory character of the security, but I do not see that there is practically any very great value in it in that respect, because any corporation that has power to borrow, and to borrow upon the security of their borough rate or their water rate, necessarily can borrow to any extent required; there is no limit to the borough rate, even if we had not that special power for making a public rate, but only power to borrow on our borough rate. We have the power to make a borough rate to any extent which is required to meet the requirements of the corporation.

7394. You are acquainted with all the district of Lancashire; could you mention the names of the chief towns which, like Manchester, have taken the waterworks into the hands of the corporation?—I find that the supply of water is in the hands of the corporations in Ashton-under-Lyne, Bolton, Bradford, Halifax, Leeds, Liverpool, Oldham, Preston, Rochdale, and Stayley Bridge.

7395. I gather from your own experience in the case of Manchester that you are thoroughly convinced of the advisability of all corporations undertaking the water supply themselves?—I am perfectly convinced of it. I think the reasons are unanswerable, and one of the strongest reasons is, first of all, that they may obtain power to rate the inhabitants, which I do not suppose would be granted to any private company; they get power to rate everybody whether they take water or not, so as to spread the expense over the largest possible area, and they get that which after all is one of the objects of greatest importance, and I think so reasonable and so just—they get power to tax the whole of the property within the area with a public rate, which is in reduction of the expense of distributing water amongst the domestic consumers.

7396. In the case of those towns and districts which you supply beyond the limits of your own borough, are you by your Act of Parliament limited with respect to the amount which you charge them?—Yes, certainly; we supply outside the city precisely upon the same terms and in the same way as any private company would do; we are limited entirely by the clauses in our Act, and beyond the limits of the city we have just the ordinary powers which belong to any ordinary waterworks company.

7397. The rate which you charge beyond the limits of your borough is, I presume, higher than what it is in your borough?—Certainly; but there is not so very great a difference as may be supposed. As I said, the actual charge in the borough is practically 10½*d.* upon the gross assessment, and the charge outside the borough is always estimated upon the gross rental. Under our Waterworks Act it is five per cent. upon gross rental that we are authorized to charge; therefore the charge outside is as 1*s.* in the pound to 10½*d.* in the pound inside, that is, including the 3*d.* public rate and the 9*d.* domestic rate. But then in addition there is a power to charge which we have never exercised, but which I think is exercised by most companies, for baths and a variety of other extra charges which we have never made; we have been content with the five per cent. hitherto.

7398. Are you under an obligation to supply those districts?—No, none whatever, except in one case. I think in the case of Salford it is under an arrangement made by Act of Parliament but in the other districts arrangements have been voluntarily entered into with the corporation to supply them; they are not under any obligation.

7399. Would you have thought it objectionable if in your case, when you were going for such large powers, you had been laid under any obligation to supply particular districts, assuming always that there was an abundance of water to do it?—I should have thought it anything but an undesirable arrangement, because, of course, if we had been put under an obligation to supply them we should have been perfectly justified in saying that they should have been put also under an obligation to come to us as customers, and it would have been a great advantage to us to have known that we were not only going to get certainly the money which would be obtained within the area of the corporation, but that we were also going to secure, as a matter of equal certainty, customers outside. The expense of getting the water is a fixed expenditure, and if we had got several millions of gallons of water a day which run to waste, which is the fact, of course we should have so much in aid of our expenditure if we could find additional customers; so that instead of its being a disadvantage, it appears to me that it would be a very great advantage, and a great encouragement to lay out a large sum of money to obtain an ample supply.

7400. (*Chairman.*) Will you put on our minutes a reference to the several Acts under which you are acting, and a description of the Acts?—The first Act obtained was the 10 & 11 Vict., cap. 203, "The Manchester Corporation Water Acts, 1847," by which the purchase of the works of the old company and the carrying out of the Longdendale scheme was authorized. The following Acts have been since obtained, by which additional powers of various kinds relating to the waterworks have been obtained by the corporation, viz.: 14 & 15 Vict. c. 79, The Manchester Corporation Waterworks Act, 1851; 17 Vict. c. 38, The Manchester Corporation Waterworks Act, 1854; 21 & 22 Vict. c. 87, The Manchester Corporation Waterworks Act, 1858; 23 Vict. c. 93, The Manchester Corporation Waterworks Act, 1860; 26 & 27 Vict. c. 68, The Manchester Corporation Waterworks Act, 1863; 28 & 29 Vict. c. 145, The Manchester Corporation Waterworks Act, 1865; 30 Vict. c. 37, The Manchester Corporation Waterworks Act, 1867.

7401. Have you any other statement which you think would be useful to this Commission?—Yes, I have a statement, which I will put in, of the charges for houses at 10*l.* and under in Manchester and several other places. It states the gross annual value, the full nett annual value, and the Manchester external and internal supply in two columns, and the charge in Glasgow, Liverpool, Dublin, Bristol, and Birmingham. I will just take one or two instances—3*l.* 10*s.* gross annual value at Manchester is 3*l.* nett annual value; for that our charge is 4*s.* externally by a stand-pipe, and 5*s.* internally, as I have explained, and it is the same up to 10*l.* We have power by the Act of Parliament to make a minimum charge of 4*s.* where externally supplied, and 5*s.* if internally supplied. In fact, we have a right to claim from the owner as the minimum charge 4*s.* or 5*s.* per annum, as the case may be, no matter what the rent of the premises may be, for a supply of water. In Glasgow the charge is 3*s.* per annum; in Liverpool, 1*s.* 8*d.*; in Dublin, 3*s.*; in Bristol, 5*s.*; and in Birmingham, 6*s.*

7402. Are all those towns supplied by the municipality or by private companies?—Glasgow is supplied by the municipality, Liverpool is supplied by the municipality, and Dublin is supplied by the municipality, and Bristol and Birmingham are supplied by companies. At Bristol the least charge is 5*s.*; and at Birmingham 6*s.* This table, which I will hand in, shows the rate from 3*l.* 10*s.* to 12*l.* Above 8*l.* gross annual value, or 6*l.* 10*s.* net, our charge would be 4*s.* 10*d.* externally, and 5*s.* internally; in Glasgow it is 6*s.* 6*d.* externally; in Liverpool, 3*s.* 8*d.*; in Dublin, 6*s.* 6*d.*; in Bristol, 8*s.*; and in Birmingham, 10*s.* 4*d.* They very soon leave us behind when we get to a little higher rentals. Then, going to 12*l.* gross, or 10*l.* net value, the Manchester charge is 7*s.* 6*d.*, either externally or internally; Glasgow, 10*s.*; Liver-

J. Heron, Esq.
2 April 1868.

pool, 5*s.* 8*d.*; Dublin, 10*s.*; Bristol, 12*s.*; and Birmingham, 16*s.* 9*d.*

7403. (*Sir B. Phillips.*) In all those cases where they are supplied by companies it would appear that the water is much more expensive than where they are supplied by corporations?—Yes; in Birmingham it is 16*s.* 9*d.*, that is a company; and in Bristol it is 12*s.*, and that is a company. There is no public rate in Bristol, and there is no public rate in Birmingham, so that that may be one reason why their charge for domestic supply is greater.

The witness delivered in the following table:—

Comparison of Charges for supply to Cottages in various Towns.

Gross Annual Value.	Full net Annual Value.	Manchester.		Glasgow.	Liverpool.	Dublin.	Bristol.	Birmingham.
		External Supply.	Internal Supply.					
£ *s.*	£ *s.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*	*s. d.*
3 10	3 0	4 0	5 0	3 0	1 8	3 0	5 0	6 0
4 0	3 0	4 0	5 0	3 0	1 8	3 0	5 0	6 0
4 10	3 10	4 0	5 0	3 6	1 11	3 6	5 0	6 0
5 0	4 0	4 0	5 0	4 0	2 3	4 0	5 0	6 0
5 10	4 10	4 0	5 0	4 6	2 6	4 6	6 0	8 0
6 0	5 0	4 0	5 0	5 0	2 10	5 0	6 0	8 0
6 10	5 10	4 1	5 0	5 6	3 1	5 6	7 0	8 0
7 0	5 10	4 1	5 0	5 6	3 1	5 6	7 0	8 0
7 10	6 0	4 6	5 0	6 0	3 5	6 0	8 0	8 0
8 0	6 10	4 10	5 0	6 6	3 8	6 6	8 0	10 4
8 10	7 0	5 3	5 3	7 0	3 11	7 0	9 0	10 4
9 0	7 10	5 7	5 7	7 6	4 2	7 6	9 0	10 4
9 10	8 0	6 0	6 0	8 0	4 6	8 0	10 0	10 4
10 0	8 0	6 0	6 0	8 0	4 6	8 0	10 0	10 4
10 10	8 10	6 4	6 4	8 6	4 9	8 6	11 0	16 9
11 0	9 0	6 9	6 9	9 0	5 1	9 0	11 0	16 9
11 10	9 10	7 1	7 1	9 6	5 4	9 6	12 0	16 9
12 0	10 0	7 6	7 6	10 0	5 8	10 0	12 0	16 9

The witness withdrew.

Adjourned *sine die.*

Wednesday 9th December 1868.

PRESENT:

Sir JOHN THWAITES in the Chair.

Alderman Sir Benjamin Phillips.
Colonel Harness, C.B.
Thomas Elliott Harrison, Esq.
Joseph Prestwich, Esq.

J. F. Bateman, Esq.
9 Dec. 1868.

John Frederic Bateman, Esq., further examined.

7404. (*Chairman.*) We understand that you are desirous of stating shortly to the Commission the result of your experience of the rainfall during the year 1868, and correcting so far as that rainfall may render it necessary, the previous figures which you have put in. I am desired to state to you that the Commission are very anxious not to go into any other question than that single one which I have indicated?—The season extending over 1864 and 1865 was a severer period in many parts of the country than the drought of 1868, and the Commission will hardly have the fullest information unless I give the rainfall of that period also. With respect to 1868 I have obtained the most accurate information as to the result of the drought, showing the quantity of rain which was received during its continuance, and the quantity of water which was delivered at Manchester, Dublin, Liverpool, and at the Loch Katrine and Gorbals Waterworks of Glasgow, at Blackburn, and at Halifax. I can also give the returns of the actual gaugings of streams which bear very directly upon the whole question. I will give it you very shortly, and I have endeavoured to express the general results in tables.

With regard to the Manchester Waterworks, we will begin first with the drought of 1868. The drought commenced on the 27th of April and terminated on the 24th of September, a period of about 150 days. I will not trouble the Commission with all the figures which you will have before you, but there was a certain quantity of water in store on the 27th of April, and a small quantity was pumped by the Gorton pumping engine, making together a total of 2,767,000,000 gallons which the Corporation had in store and pumped by the engine for the supply of Manchester. At the end of the drought on the 24th of September there remained in store in round numbers 435,000,000 gallons, showing that out of store they had taken 2,331,000,000. The quantity supplied during the drought to the mills was in round numbers 1,623,000,000 gallons, and to the city 1,839,600,000 gallons, making together 3,462,600,000 gallons in round numbers, showing that beyond the quantity which they had taken out of store, they had derived from other sources 1,131,000,000 gallons of water. That was yielded by the rain and springs during that period, and the quantity amounted to a depth of 2·77 inches of rain flowing from the 18,000 acres of drainage ground which constitutes the collecting ground of the Manchester Waterworks, or to an average flow during the whole of that period of ·776 of a cubic foot per second from every 1,000 acres. The following table will show how these results are arrived at:—

MANCHESTER CORPORATION WATERWORKS.—DROUGHT of 1868.

The drought commenced on the 27th April and terminated on the 24th September, a period of about 150 days.

	Gallons.
Quantity of water in store April 27th	2,740,000,000
Pumped by the Gorton engine between August 12th and October 8th	27,000,000
	2,767,000,000
Quantity of water in store, 25th September	435,679,203
	2,331,320,787

Quantity supplied during the drought.

			Gallons.
To mills full supply to 10th August, 105 days, at 12,728,568 per day			1,336,499,640
From 10th August to 24th September, 45 days, at 6,364,284 per day			286,392,780
Total to mills			1,622,892,420
To City.			
Unlimited constant supply to 3d August, 98 days, at 14,330,450	1,404,484,145		
From 3d August to 24th September, the above water was shut off at night from 6 p.m. to 6 a.m., 52 days at 8,368,008	435,136,407	1,839,620,552	3,462,512,972
Balance being the quantity supplied by springs and rain			1,131,192,185

The yield of rain and springs is equal to 2·77 ins. of rain flowing off the 18,000 acres of drainage ground, or to a flow of ·776 cubic feet per second from every 1,000 acres. The rain during this period was 9 ins.; the loss therefore, 6·23 inches.

The diagram which I have placed before the Commission shows what the water in store in the Manchester Waterworks, during all those years from 1864 to 1868 was, the red horizontal line representing the ordinary level of the storage, and the other lines representing the manner in which the reservoirs went down during those years. We increased our storage in March 1868 but the drought this year brought the quantity down to 435,000,000 gallons, which was the lowest point on the 24th of September. The ·776 which I have mentioned is the mean result of the 150 days, but in order to show how the streams went down, and what their produce was during that period in which it may be said that no rain fell, which was from May to August—I have worked it out in four different periods:—

MANCHESTER CORPORATION WATERWORKS.—DROUGHT of 1868.

Memorandum as to yield of streams during periods of minimum rainfall.

1st.—From June 1st to 29th 1868=28 days. Rainfall at Rhodes Wood 0·58 ins.—at Woodhead 0·42 ins.

			Gallons.
Quantity in store June 1st 1868	both exclusive of		2,287,000,000
Do. „ 29th „	Prestwich Reservoir		1,693,000,000
Quantity supplied out of store			594,000,000
Quantity supplied:			
To City—14,440,180 gallons per day on the average for 28 days		404,325,037	
To Mills—14,850,000 gallons per working day for 24 days		356,400,000	
Total quantity supplied		760,725,037	
Deficiency supplied by district			166,725,037
			760,725,037

166,725,037 gallons, or 26,676,006 cubic feet, equal ·612 cubic feet per second from every 1,000 acres.

2d.—From June 29th to August 3d 1868 = 35 days. Rainfall at Rhodes Wood 0·68 ins.—at Woodhead 0·66 ins.

		Gallons.
Quantity in store, June 29th 1868, including estimated quantity in Prestwich Reservoir		1,713,000,000
Do. August 3d „	do.	893,000,000
Quantity supplied out of store		820,000,000
Quantity supplied:		
To City—14,884,606 gallons per day on the average for 35 days	520,961,208	
To Mills—14,850,000 gallons per working day for 30 days	445,500,000	
	966,461,208	
Balance being produce of the district		146,461,208
		966,461,208

146,461,208 gallons, or 23,433,791 cubic feet, equal to ·43 cubic feet per second from every 1,000 acres.

3rd.—From July 27th to August 3d, 1868 = 7 days. Rainfall at Rhodes Wood 0·10 ins.; at Woodhead, 0·11 in.

	Gallons.
Quantity taken from store during this period	171,000,000
Quantity supplied:	
To City—14,900,000 gallons per day on the average for 7 days	104,300,000
To Mills—14,850,000 gallons for every working day for 6 days	89,100,000
Total supplied	193,400,000
Balance being the produce of the district	22,400,000
	193,400,000

22,400,000 gallons, or 3,584,000 cubic feet, equal to 0·329 cubic feet per second from every 1,000 acres.

J. F. Bateman, Esq.

9 Dec. 1868.

4th.—From June 1st to August 3d, 1868 = 63 days. Rainfall at Rhodes Wood=1·26 ins.; at Woodhead=1·08 ins.

	Gallons.
Quantity in store June 1st, 1868, including estimated quantity in Prestwich Reservoir - -	2,307,000,000
„ August 3d „ do. - -	893,000,000
Quantity taken from store - - - - - - - - -	1,414,000,000
Quantity supplied:	
To City—14,687,083 gallons per day on the average for 63 days - - -	925,286,245
To Mills—14,850,000 gallons per working day for 54 days - -	801,900,000
	1,727,186,245
Balance produce of the district for 63 days - - - - - - - -	313,186,245
	1,727,186,245

313,186,245 gallons, or 50,109,799 cubic feet = ·5114 cubic feet per second from every 1,000 acres.

SUMMARY.

	Cubic feet per second from every 1,000 acres.
District produced between June 1st and 29th, 1868, 28 days (with ·58 ins. of rain at Rhodes Wood and ·42 ins. of rain at Woodhead) - - -	0.612
„ June 29th and August 3d, 1868, 35 days (rainfall at Rhodes Wood, 0·68 ins.; rainfall at Woodhead, 0·66 ins.) - - -	·43
„ July 27th and August 3d, 1868, = 7 days - - - -	0·329
„ June 1st and August 3d, 1868, = 63 days - - - -	0·5114

First of all, from the 1st of June to the 29th of June, 28 days, the rainfall was about half an inch; and the produce of the district was equal to ·612 of a cubic foot, or just two-thirds of a cubic foot per second from every 1,000 acres. Then from the 29th of June to August 3d, the rainfall being exactly two-thirds of an inch in that time, the produce of the district was ·43 of a cubic foot per second from every 1,000 acres. That was the average of that period. At the end of July and the beginning of August the streams had got down to their lowest. From the 27th of July to August 3d, seven days, there being only one-tenth of an inch of rain, the produce of the district was ·329 of a cubic foot per second from every 1,000 acres. From June 1st to August 3d, which includes the whole period during which I have given the separate details in three different portions, the average produce of the district was ·5114 of a cubic foot per second from every 1,000 acres. It will be in the recollection of the Commission that I stated in my previous evidence that the average yield of this district was as nearly as possible half a cubic foot per second from every 1,000 acres during the continuance of a drought. That was true for a period of about 70 days, but the average of the 150 days, which included the time during which the streams were somewhat swollen after the termination of the wet weather in March and April, was nearly eight-tenths, or, speaking more accurately ·776 of a cubic foot per second per 1,000 acres. So that while I was quite correct as to the quantity of water yielded during the extremity of the drought during which it may be said that no rain fell, I under-estimated the ordinary produce of the district during the 150 days of what for waterworks purposes would be considered drought, but would not be considered drought for agricultural purposes. At the end of the above Table you will find stated shortly the figures I have given —in the first division ·612, in the second ·43, in the third ·329, and the average of the whole period ·5114. These results are given from the quantity of water actually collected in the reservoirs, (which during that time did not run over,) the capacity of which we know at every inch in depth, and from the quantity of water actually delivered as measured through gauges. During a portion of that period, for another purpose entirely, I had the streams flowing from rather more than 3,000 acres in the upper portion of the drainage district of the Manchester Waterworks carefully measured. That was at the commencement of August, and on referring to the table I have given you will see that the gross produce of the whole district was ·329 of a cubic foot per second. From the 3,000 acres which formed a portion of that, and which was by no means the most productive portion as regards spring water, it averaged ·28, being a little less than the average of the whole 18,000 acres from which the water is obtained. I merely mention that to show how nearly one corroborates another.

7405. Did you gauge at the point of discharge into the reservoir?—The first measurements which I gave, are measured as it were by a great basin, because the reservoirs are in fact great bowls into which the water is received from the whole 18,000 acres, and we know their capacity at every inch in depth.

7406. How did you measure the net result of the rainfall on the 3,000 acres?—Over a gauge put down across the stream, through a notch.

7407. And did one stream take the whole?—No, there are two streams—one bringing the water from 1,751 acres, and the other from 1,436 acres, making together 3,187 acres.

7408. Did you make a section of the stream?—We put a gauge across it, and measured the depth flowing over it, and ascertained the volume by well-known formulæ. I can also show the Commission by diagrams (See Appendix B. H.), which are very valuable indeed, the results of gauging which were taken during the same period at the Halifax Waterworks. One diagram shows the quantity of water flowing from two streams in the Halifax Waterworks, one of which has a drainage area of 2,325 acres, and the other of 1,999 acres. During January, February, and March, it was very wet, April was dry till towards the end of it—and from that time to the beginning of August with very little exception it is a continual decrease in quantity. At the commencement of August there is an almost uniform slight increase, and if you look at both the streams you will observe that they exactly correspond and tell the same story. I want to show how closely correspondent all those districts are with reference to the yield of water. In May, from the period at which the flood may be said to have run off, the average volume of the stream, swollen occasionally by slight showers, was ·554 of a cubic foot per second per 1,000 acres; in June, very little rain indeed having fallen, it was ·28 of a cubic foot per second per 1,000 acres; in July, still without rain, it was ·225 of a cubic foot per second per 1,000 acres; in August, a little rain having fallen during the period to which those observations apply, it was ·272 of a cubic foot per second per 1,000 acres; and the average of the whole period, from about the 4th of May to the 21st of August, or a little beyond the middle of August, was ·332 or one-third of a cubic foot per second from each 1,000 acres during that most extraordinary drought of 1868. Then if you go to the River Hebden, which has a drainage area of upwards of 9,000 acres, and therefore taking a larger portion of spring water, you find that in May the average quantity from those 9,000 acres was ·756 of a cubic

oot per second per 1,000 acres; in June, ·418; n July, ·305, and in August ·324, the average of the whole period being ·452, coming very closely upon he half cubic foot per second which I stated was the general result; and if you take that with what is the case at Manchester, which is ·5114, you almost exactly get half a cubic foot per second as the mean between the two series of observations.

I would wish to take Liverpool separately, because it is very important information which Liverpool gives, and it would be convenient to keep it all together, embracing as it does a period of five years from 1861 to 1865 inclusive, which included 1864 and 1865, very severe years, and then 1864, 1865, and 1866, together with the long drought of 1868; therefore, instead of Liverpool, I will now take the case of Dublin in 1868, and hand in the following table:—

DUBLIN WATERWORKS.—DROUGHT of 1868.

Drainage ground - - -	acres	14,080
Capacity of reservoir, Vartry Lough -	c. ft.	380,000,000
Or	gallons	2,374,358,300

Equal to 25,568 cubic feet of storage to each acre of ground.

Drought commenced May 1st, ended Sept. 18th=141 days.

	Gallons.
Quantity of water in store at commencement	1,590,176,513
Ditto end of drought - - -	877,731,138
Total drawn from stores - -	712,445,375
Quantity discharged from reservoir during this period - - - -	2,109,728,160
Supplied by streams and rain - -	1,397,282,785

Equal to 1·303 cubic feet per second from every 1,000 acres, and to 4·37 ins. of rain flowing off ground out of 11·298 ins. which fell.

The drainage ground to the Dublin Waterworks is 14,080 acres; the capacity of the Roundwood reservoir or Vartry Lough is 380,000,000 cubic feet. At the commencement of the drought, which was on the 1st of May, the Vartry reservoir, which had only been recently repaired, was not full, but it contained 1,590,000,000 gallons of water; at the end of the drought it contained about 878,000,000 gallons. There were therefore drawn from store 712,000,000 gallons; and the quantity discharged from the reservoir during this period for the supply of Dublin was 2,109,000,000 gallons, showing that they had obtained from other sources 1,397,000,000 gallons. That of course was obtained by the produce of the streams and rain, the whole quantity being equal to 1·303 cubic feet per second from every 1,000 acres, and to 4·37 inches of rain flowing off the ground out of 11·298 inches which fell in that period. The drought continued during 141 days, and you will see that the produce of the streams during those 141 days was one and one-third cubic foot per second, very nearly, as against ·776 of a cubic foot per second, which the Manchester water works district yielded during the same period within nine days.

7409. There is therefore a much larger net result in this case than in the case of Manchester?—Yes, a much larger net result. The next case that I will give is that of Glasgow for 1868, and first of all of the Loch Katrine district—with regard to which I will hand in the following table:—

GLASGOW CORPORATION WATERWORKS.—DROUGHT in the LOCH KATRINE DISTRICT, 1868.

Drought may be said to have commenced on the 30th May and ended on the 8th August, or 70 days.

		Gallons.
Water in store in Lochs on 30th May 1868 - - - - - - - -		8,640,109,163
Quantity of water discharged from Loch Katrine to service reservoir, from 30th May to August 8th, 1868, = 24,174,990 gallons daily - - - - - - -	1,692,249,308	
Quantity of water discharged from Loch Venechar during same period as compensation, =48,712,206 gallons daily - - - - - - - -	3,409,854,432	
Total supplied - - - - - - -	5,102,103,740	
Quantity in store on 8th August - - - - - - - - -		4,991,217,229
Quantity supplied out of store - - - - - - - - -		3,648,891,234
Quantity produced by stream and rain during the period of 70 days - - - - -		1,453,212,506
Total supply - - - - - - - - - -		5,102,103,740

The quantity supplied by rain and springs during the drought was equal to 0·839 cubic feet per second from every 1,000 acres of drainage, and to 1·39 ins. of rain from 45,800 acres out of 4·65 ins. average rainfall during this period.

Storage provided (8,640,000,000 gallons, or 1,382,400,000 cubic feet) equal to 30,183 cubic feet for every acre of drainage ground.

Scheme intended to supply to city - - - - -	50,000,000	gallons per day.
And compensation to streams - - - - - - -	40,500,000	„ „
Total supply - - - - - - - -	90,500,000	„ „

Storage and streams (8,640,109,163 storage + 1,453,212,506 streams and rain = 10,093,321,669 gallons), would supply 90,500,000 gallons daily for 70 days, and leave in store at the end of that time 3,758,321,669 gallons, equal to the supply of the same quantity for 41½ days more, even supposing the streams to yield nothing during these 41½ days, and they would probably have yielded 20,000,000 gallons per day, so that the storage would have lasted for upwards of 50 days, making up the 120 days provision on which the scheme was laid out.

The drought there was not a long one; it hardly may be considered a drought at all, for it lasted only about 70 days, beginning on the 30th of May and ending on the 8th of August. The gross result of that was that the quantity supplied by rain and springs during those 70 days (which you will observe included that extreme period of June and July up to the 8th of August, which produced that very small quantity of rain in Halifax and Manchester, as I have already shown you), was ·839 cubic feet per second from every 1,000 acres, being equal to 1·39 inches of rain from 45,800 acres of drainage ground out of 4·65 inches which actually fell during the period.

7410. That is less than the other result?—Yes, but it is only for 70 days.

7411. Is not the ratio less?—No, it is rather more; it is about one-third. The produce of the district during those 70 days was equal, if it had been all the result of rain, to 1·39 inches out of 4·65 inches which actually fell.

7412. That is less than the proportion in the case of Dublin?—Yes, but the drought at Dublin extends over 141 days. We only drew from Loch Katrine and Loch Venechar for the supply of the mills and the city together, about 73,000,000 gallons of water per day, being 48,750,000 gallons as compensation to the river, and rather more than 24,000,000 gallons to the city of Glasgow. We are entitled to take for Glasgow 50,000,000 gallons a day. I therefore worked out what would be the quantity of water which we should be able to supply, and for how many days, supposing we were drawing the full

J. F. Bateman, Esq.

9 Dec. 1868.

50,000,000 gallons and giving the full amount of compensation, and I find that we should have been able to have supplied the full quantity of compensation, and the full amount of 50,000,000 gallons per day for 120 days, which is exactly the period upon which the Loch Katrine Waterworks were originally designed before our experience of the drought of 1864 and of 1865, or of 1868—so that the Loch Katrine Waterworks proved to be equal to the supply to the very day to which I calculated them in 1853 or 1854, when I laid them out, and the calculation seems to be correct, even in a drought like that of 1868.

The Gorbals Waterworks is the next case, as to which I will hand in the following table :—

GLASGOW CORPORATION WATERWORKS, GORBALS DISTRICT.—DROUGHT of 1868.

Drainage area - - -	acres	2,560
Capacity of reservoirs - -	cubic feet	134,239,786
Or - -	gallons	838,998,662

Storage equal to 52,437 cubic feet per acre.

Average rainfall per annum - - -	inches	49
Average loss - - - - -	,,	10¼
Available rain - - -	,,	38¾

Drought of 1868 extended over 189 days, commencing March 29th, and terminating October 3d.

	Gallons.
Quantity of water in store at commencement	838,998,662
In store at end of drought - - -	220,591,199
Taken from store - - -	618,407,463
Quantity of water delivered during the period to city and to river for compensation, average 5,256,581 for 189 days - -	993,493,836
Supplied by rain and streams -	375,086,373

The quantity supplied by rain and springs during the 189 days was equal to 1·43 cubic foot per second from every 1,000 acres; and to 6·45 ins. of rain over the whole drainage ground, out of 18·19, the actual rainfall.

The quantity of water actually delivered was at the rate of nearly 33 ins. of rain collected per annum. The water left in store was equal to about 7 in. more, together, 40 in.

This is a very useful instance, for the drought in 1868 there lasted over 189 days. The drainage area is 2,560 acres; the capacity of the reservoirs is 134,000,000 cubic feet, equal to a storage of 52,437 cubic feet per acre. A great deal depends upon the amount of storage in proportion to the contributing area as to the means which we have of giving a large supply. The result in this case is that after making allowance for that which was taken out of store, and putting against that the quantity which was actually delivered, we find that there were supplied by rivers and streams 375,000,000 gallons during the period of 189 days as against 618,000,000, which was taken out of store. The quantity supplied by rain and springs during this period was equal to 1·43 cubic feet per second per 1,000 acres, or nearly a foot and a half—and to 6·45 inches of rain over the whole drainage ground, out of 18·19 inches, which was the actual amount of rainfall during the period. The quantity of water actually delivered was at the rate of nearly 33 inches of rain collected per annum, and the water left in store was equal to about 7 inches more—so that with that amount of rainfall, and with a storage equal to about 52,000 cubic feet per acre, they were capable of delivering through a drought like that of 1868 at the rate of 40 inches of rain per annum actually collected.

The next case that I will take is that of Blackburn. This, although a very small acreage, and a small supply, is a case deserving of considerable attention, and I will hand in the following table :—

BLACKBURN WATERWORKS.—DROUGHT of 1868.

Population supplied about - -	persons	60,000
Average daily supply - -	gallons	1,150,000
Drainage ground for town purposes	acres	880
Gross capacity of reservoirs for ditto	gallons	410,000,000
Or	cubic feet	65,600,000

Being equal to 74,545 cubic feet per acre of drainage ground.

The drought commenced on the 27th March. The reservoirs were not then full.

	Gallons.
The quantity of water in store was approximately - - - - - -	300,000,000
The drought ended about the middle of September, say the 25th, the same as in Macchester. The quantity then in store was about - - - - - -	104,000,000
Taken out of store - -	196,000,000
Supply to town for 182 days at 1,150,000 gallons per day - - - -	209,000,000
Supplied by rain and springs - -	13,300,000

The quantity supplied by rain and springs during the 182 days of drought was only equal to ¾ of an inch in depth over the drainage ground out of 12·8 ins. of rainfall, but these calculations, though very near the truth, are only approximate.

The present supply to Blackburn is equal to but 19 inches of available rain. The reservoirs once full are equal to 20½ ins. depth of rain over the whole drainage ground, and would, therefore, give out a quantity equal to that depth for a whole year, without any aid from rain, or to 41 in. for a period of 186 days.

The rainfall on the average of 10 years is 44 ins., and the reservoirs are capable of utilizing more than the average available rain. They have been made in anticipation of receiving supplies from additional ground which has not yet been appropriated.

Formerly they had only a small amount of storage in proportion to the ground which they had to collect from, and in a season like that of 1868, they would have been short of water, although they were supplying but a portion only of that which actually flowed from the ground; but in course of last year we completed a very large reservoir which was intended to hold the water of a large district, which, however, has never been brought to it. Now the reservoirs collect every drop of water which falls, and would collect more than what falls, and that will last them for some time longer. The drainage area contributing to the supply of the town is only 880 acres, but the gross capacity of the reservoirs as they now exist is 410,000,000 gallons, being equal to 74,545 cubic feet of water storage for every acre of collecting ground. The population is about 60,000, and the average daily supply is 1,150,000 gallons. I cannot give you those calculations with absolute correctness, because of the older reservoirs we have not the capacity at every inch in depth, of the new one we have, but those calculations are very near the truth.

7413. Can you give us the net result?—Yes. The quantity of water in store on the 27th of March, when the drought commenced, was 300,000,000 gallons; at the end of the drought on the 25th of September, there remained 104,000,000 gallons in store; there were therefore taken out of store 196,000,000 gallons; and the supply to the town during that period, which was 182 days, was 209,000,000 gallons, leaving the quantity supplied by rain and springs 13,300,000 gallons, that is equivalent to only three-fourths of an inch in depth over the drainage ground, out of 12·8 inches of rainfall; but as I said before, those calculations are only approximate. It is a bare hill side of nearly 900 acres, with scarcely a spring upon it; but the important result is that where you have a very large amount of reservoir room, you may in fact store not only all the rain which falls in average years, but that which falls in excessively wet years; and with such reservoirs as they have at Blackburn, not one single drop of water which flows off the ground need be run to waste. If they were only to deliver water equivalent to the average supply, there would not be one single drop of water run to waste, and they would be able to give the full average of the whole available quantity flowing from the district.

7414. How do you explain this, that in a very hilly district of 900 acres you have the result of but three-fourths of an inch available for the water supply out of 12·8 inches?—I am not quite sure as to the calculations being correct within three-fourths of an inch. It was excessively dry there during that period—it is a pastoral district which is covered with vegetation and wholly grassland—and during that period a large portion of the rainfall would no doubt be absorbed by vegetation.

7415. If it is a hilly district, the water would find its way more rapidly into the channel, would it not?—That is governed by the nature of the vegetation, but I believe the three-fourths of an inch to be less than the truth. I have no doubt that if those calculations were accurately taken, the three-fourths of an inch would have to be doubled, or perhaps more.

7416. Will you now take the case of Liverpool?—Yes. I propose to give you Liverpool, first, for the whole series of five years commencing with 1861 and ending with 1865, then for the drought, which in Liverpool extended from March 1864 to June 1866, (and that was the most trying period that I find they have ever passed through, or any waterworks have passed through within any record), and then for the drought of 1868:—

LIVERPOOL CORPORATION WATERWORKS, RIVINGTON.—1861 to 1865 inclusive.

Drainage area - - - -	acres	10,000
Average rain for 17 years - - -	inches	46
Mean rains of 1861 to 1865 inclusive=five years	„	44
Mean of 64 and 65 being only - - -	„	37

Storage 2,940,000,000 gallons, or 470,000,000 cubic feet, = 47,000 cubic feet per acre.

Average yield per day during above period:—

	Gallons.
To mills for compensation - - -	8,300,000
To town and work - - -	12,472,672
	20,772,672

Equal to 3,323,630 cubic feet × 365 day = 1,212,064,950 cubic feet.

10,000 acres = 435,600,000 square feet, = 2·782 or 33½ in. gross produce of district out of 44 in., showing a loss of 10½ ins.

Quantity actually collected and delivered:—

	Gallons.
To River as compensation - -	8,300,000
To town - - - - -	10,544,112
	18,844,112

Being equal to 30 ins. or 10 per cent. less than the average yield.

The drainage area of the Liverpool Waterworks is 10,000 acres, the average rainfall for 17 years is 46 inches, the mean rain of the five years under consideration, 1861 to 1865 inclusive, was 44 inches, the mean of 1864 and 1865, being the two dryest years which occurred during that period, was only 37 inches; the storage was then equal to about 47,000 cubic feet per acre. The average yield per day during the above period, taking mills, and town, and waste together, that is to say, the gross quantity which flowed off the ground, was 20,770,000 gallons per day, equal to a gross produce in the year of 33½ inches per annum out of 44 inches, which fell during that period, showing a loss by evaporation, absorption, and so on of 10½ inches. The quantity actually collected and delivered was 18,844,000 gallons per day, being equal to 30 inches of water actually delivered, or 10 per cent. less than the average yield. Then the next information with reference to Liverpool that I have to give to the Commission, is with regard to the drought of 1864, 1865, and 1866, of which the following table is a summary:—

LIVERPOOL CORPORATION WATERWORKS.—DROUGHT of 1864, 1864, and 1866,

	Gallons.
Reservoirs full on 11th March 1864 -	2,940,000,000
On 28th October 1865, being then at their lowest point - - - -	228,000,000
Decrease - - -	2,712,000,000

During the same period there was taken to Liverpool and given to rivers, 596 days — Gallons. 11,240,000,000

Obtained from springs and rain - 8,528,000,000

$$\frac{11{,}240{,}000{,}000}{596} = 18{,}860{,}000 \text{ gallons per day.}$$

Or To mills 8,300,000

To town 10,560,000

The reservoirs being then nearly exhausted, and a winter of only moderate rainfall following, this supply could not have been maintained, for the average yield of the first five months of 1866 was only (8,736,000 + 8,300,000) 17,036,000 gallons per day. Supposing this to represent the yield of November and December, the works would have given the full compensation to the mills, and rather more than 9,000,000 gallons per day to the town, say with safety 17,300,000 = 28 inches per annum.

The reservoirs were full or very nearly full on the 11th of March 1864, and they then contained 2,940,000,000 gallons; they reached their lowest point on the 28th of October 1865, having then fallen to 228,000,000, therefore the store had decreased 2,712,000,000 gallons. During the same period, that is for 596 days, there were taken to Liverpool and given to the river 11,240,000,000 gallons, showing that there was obtained from springs and rain 8,528,000,000. The reservoirs being then nearly exhausted, that is to say, in October 1865, and a winter of only a moderate rainfall following, the supply could not have been maintained at what they had been giving, which was an average of 18,800,000 gallons per day, that being composed of 8,300,000 gallons as compensation to the mills, and 10,560,000 to the town. They could, with safety, have given, up to the 1st of June 1866, when the drought ceased, 9,000,000 gallons per day to Liverpool, or rather more, and the full amount of compensation, that is, 8,300,000 gallons, making a total of 17,300,000 during that extreme period. Therefore, as they were delivering and had delivered 10,560,000 gallons previous to their extremity in October 1865, they had been exceeding their means of supply by about 1,500,000 gallons per day, and they ran short at the end of 1865. They were obliged to diminish their supply in consequence of having been delivering up to that period more than the quantity which their district enabled them to give. With the storage that they then had, they could have delivered throughout that period 1864 and 1865, and up to Midsummer 1866, a quantity equal to 28 inches of rainfall per annum. They got an Act of Parliament in 1866, by which they were enabled to make additional storage, and that would enable them to collect the waste water of wet periods and to add about 1,250,000 gallons per day to the 9,000,000, so that when that reservoir is completed, and they are now constructing it, they will be in a condition to deliver through such a period as 1864 and 1865, about 10,250,000 gallons per day to the town of Liverpool, besides giving full compensation to the mills at the amount at which such compensation stood up to 1866.

The following table gives the state of things for the year 1868:—

LIVERPOOL CORPORATION WATERWORKS, RIVINGTON DISTRICT.—DROUGHT of 1868.

Drainage area - -	acres	10,000
Capacity of reservoirs - -	cubic feet	485,000,000
Or - -	gallons	3,025,000,000

Storage equal to 48,500 cubic feet per acre.

Drought of 1868 extended over 161 days, commencing April 28th and terminating October 6th.

Quantity of water in store at commencement	3,025,000,000
In store at end of drought - - -	722,000,000
Taken from store - - -	2,303,000,000

Quantity of water supplied during this period
to city - 9,987,570 gallons per day
And for compensation to river - 6,465,840

Total daily aver. 16,453,410 for 161 days = 2,649,000,000

Supplied by rain and springs - - 346,000,000

J. F. Bateman, Esq.

9 Dec. 1868.

The quantity supplied by rain and springs during the 161 days of drought was equal to ·398 cubic feet per second, for every 1,000 acres of drainage, and to 1·525 inches of rain flowing off the whole drainage ground out of 12·20 inches which fell during this period.

If the whole of the water in store at the commencement had been exhausted at the end of 161 days of drought, it would have represented a total daily supply from the district equal to:—

	20,937,880 gallons per day.
Deducting for compensation a portion having been purchased	6,465,840
Left for town	14,472,040

In 1868 the drought extended over 161 days, commencing on the 28th of April, and terminating on the 6th of October; it lasted longer in Liverpool than it did in some of the surrounding districts. The quantity yielded by rain and by springs during that period was equivalent to ·398 of a cubic foot per second for every 1,000 acres, or to 1·525 inches of rain out of 12·20 inches which fell. The district yielded a very small amount of actual contribution to the reservoirs during that period of drought; they only got 1½ inches out of about 12 inches which fell, showing that they lost 10½ inches, but a large portion of the Liverpool drainage ground is flat land; it nowhere rises to more than 1,200 or 1,300 feet, and the mean elevation of the whole district is only between 700 to 800 feet, and there is a great deal of peat upon the tops of the hills, and a great deal of flat cultivated land on the westerly slopes of the reservoirs.

7417. Then if the general water line were depressed, especially on peaty soil, the absorbing power would be enormous?—Yes. It is a strong contrast to the state of Manchester and the state of Dublin. They could have delivered during the drought of 18 rather more than 12,000,000 gallons to the town of Liverpool, had the compensation to the mills remained the same; but they bought up a certain portion of the compensation in 1866, and therefore they could deliver more; but had the compensation to the mills remained the same, they could have delivered rather more than 12,000,000 gallons of water per day to Liverpool against only a little more than 9,000,000 in 1864 and 1865.

I will now refer to the drought of 1864 and 1865 in Manchester, and will hand in the following table:

MANCHESTER CORPORATION WATERWORKS, DROUGHT OF 1864.

	Acres.
Drainage area	18,000
Drought commenced May 24 and ended October 11th, lasting 140 days.	Gallons.
Quantity of water in store at commencement	1,779,000,000
Do. at end of drought	1,253,000,000
Quantity taken from store	526,000,000
Quantity supplied during this period:	
	Galls. pr. day.
To mills for compensation	12,728,568
To town supply on average	11,070,000
Total daily	23,798,568
	× 140 days = 3,331,799,520
Supplied by rain and springs	2,805,799,520

The quantity supplied by rain and springs during this period is equal to 2·05 cubic feet per second from every 1,000 acres of drainage, and to 6·85 inches of rain flowing off the ground out of 15 inches actual rainfall during this period.

The drainage area is 18,000 acres; it is a little more than that, but there is an allowance to be made for some water which is abstracted by the mill owners. In 1864 the drought commenced on the 24th of May, and ended on the 11th of October, lasting 140 days. Without going over all the figures, the important object of them is to show that the quantity supplied by rain and springs during this period of drought is equal to 2·05 cubic feet per second from every 1,000 acres and to 6·85 inches of rain flowing off the ground out of 15 inches, which was the actual rainfall. The following table shows the state of things for 1865:—

MANCHESTER CORPORATION WATERWORKS, DROUGHT OF 1865.

Drainage area	18,000 acres.
Drought commenced April 18th and extended to October 8th, lasting 172 days.	Gallons.
Quantity of water in store at commencement	2,384,000,000
Ditto at end of drought	912,000,000
Quantity taken from store	1,472,000,000
Quantity of water supplied during this period	
To mills for compensation	12,728,568
To town supply	11,833,000 total.
	24,561,568 total daily.
	average × 172 days = 4,224,589,696
Supplied by rain and springs	2,752,589,696

The quantity supplied by rain and springs is equal to 1·6467 cubic feet per second for every 1,000 acres of drainage and to 6·74 inches of rain flowing off the ground out of 14½ inches actual rainfall during the period.

In 1865 the drainage area remaining the same, the drought commenced on the 18th of April, and extended to the 8th of October, lasting 172 days. After showing what we had in store at the commencement, and at the end of the drought, and what was supplied, it results that the quantity supplied by rain and springs was equal to 1·6467 of a cubic foot per second for every 1,000 acres, and to 6·74 inches of rain flowing off the ground out of 14½ inches, which actually fell during that period.

7418. You get a much greater result here?—Yes, in 1864 and 1865, although it was more severe in Liverpool; perhaps if we had been supplying quite the same quantity of water, it would have been nearly as severe in 1868.

7414. In 1864 it was 6·85 out of 15 inches?—Yes. You will see at once the state of things if you look at this diagram (*producing a diagram*). I have endeavoured to tabulate in a short form the information which I have been giving the Commission, and I want to draw their attention specially to the different amount of storage in the various districts as to which I have been giving the information, and I will hand in the following table:—

TABLE 12.—Showing the YIELD and QUANTITY of WATER supplied during the Drought of 1868 at the various Waterworks named.

Name of Place.	Drainage Ground. — Acres.	Storage available.		Drought.			Rainfall during Period of Drought, — Inches.	Flow off Drainage Ground.			Quantity actually supplied.			Equal to available Rainfall per Annum of Inches.	Total Quantity which might have been supplied had available Storage been exhausted. — Gallons per Day.	Equal to Gallons per Day from every 1,000 Acres of Drainage Ground.	Equal to available Rainfall per Annum of Inches.
		In Million Cubic Feet.	Cubic Feet per Acre of Drainage Ground.	Commenced.	Ended.	Lasted. — Days.		Equal to Rainfall of Inches.	Equal to Cubic Feet per Second per 1,000 Acres.	Equal to Gallons per Day per 1,000 Acres.	From Store. — Gallons per day.	From Springs and Rain. — Gallons per Day.	Total. — Gallons per day.				
Manchester - - -	18,000	438	24,333	1868. April 27	1868. Sept. 24	150	9 ins.	2·77	·776	419,040	15,362,139	7,541,281	22,903,420	20·47	26,399,282	1,466,627	23·6
Liverpool - - -	10,000	485	48,500	April 28	Oct. 6	161	12·20	1·525	·398	214,920	14,304,348	2,149,068	16,453,416	26·47	20,937,886	2,093,788	33·68
Dublin - - - -	14,080	380	25,568	May 1	Sept. 18	141	11·298	4·370	1·303	703,620	5,052,804	9,909,807	14,962,611	17·51	21,187,654	1,504,850	24·62
Glasgow { Loch Katrine -	45,800	1,382	30,183	May 31	Aug 8	70	4·4	1·39	·839	453,060	52,127,017	20,760,178	72,887,195	25·6	144,190,308	3,148,260	50·64
Glasgow { Gorbals - -	2,560	134	52,437	March 29	Oct. 3	189	18·19	6·45	1·43	772,200	3,271,997	1,984,583	5,256,580	33·02	6,423,729	2,509,269	40·37
Welsh district, River Severn - - -	130,000	Hill Reservoirs 6,709 | 51,390		May 1	Sept. 21	144	9·2		1·00 assumed.	540,000 assumed.					350,000,000	2,600,000	41½
		If service reservoirs at Stanmore be added 7,482	57,306	-	-	-	-	-	-	-	-	-	-	-	380,000,000 for 150 days.	about 3,000,000	48 in.

J. F. Bateman, Esq.

9 Dec. 1868.

In our Manchester Waterworks we are at present incomplete. We are behindhand in several of our reservoirs which we are now constructing, and we are beforehand with the quantity of water which we are supplying, so that we are not quite equal to what we should be in storage, and therefore we were not able to give the full supply of water which we could have desired during the last drought. Our available storage in Manchester is equal at present to only 24,000 cubic feet of water per acre of collecting ground. In Liverpool the storage is equal to 48,500; in Dublin it is equal to 25,500; at Loch Katrine it is equal to 30,000; and, at Gorbals it is equal to 52,000. The storage for Wales according to the plans which I have laid before the Commission, omitting the service reservoirs near Stanmore, is equal to 51,589 cubic feet for each acre of collecting ground. The result is that with the several amounts of storage named, the produce from each district during the drought of 1868, at all the various places where actual observations have been taken, is as follows: If you look at the heading called "Quantities actually supplied," and if you look at the column following that, you will find that in Manchester we did supply during the period of the drought for 150 days a quantity equal to 20·47 inches of annual rainfall. Liverpool did supply a quantity equal to 26½ inches. Dublin did supply at the rate of 17½ inches. Loch Katrine at the rate of 25·6, and Gorbals at the rate of 33 inches. These were the quantities actually supplied without reference to the capabilities of the district. Then if you follow on to the next columns, you will find that they had not only supplied that which was produced by the district, but they exhausted their store at the end of that drought. The quantity which they did supply during that very long drought of 1868 was equal to a depth of 20½ inches in Manchester per annum over the whole district, and if we had supplied more than 20½ inches, we should have been short during the drought.

7420. Are we to understand that this 20½ inches is 20½ inches up to January last when this table was made, or have you calculated and spread the 20½ inches over the whole 12 months?—Over the whole 12 months. The quantity which we did supply was equal to a safe supply during the drought at the rate of 20½ inches. If we had calculated upon 24 inches, we should have been 3½ inches short during the drought.

7421. When you speak of supply do you mean supply for purposes of consumption and for municipal purposes, or do you mean the quantity of water available for supply?—The first column is the actual quantity which was drawn from the reservoirs for all purposes, whether for the city, for municipal purposes, or for domestic, or for mill consumption, it was equivalent over the whole year to 21 inches.

7422. (*Sir Benjamin Phillips.*) Was it equal to your requirements?—It was nearly equal to the requirements. There were a few weeks during which we had to shut off the water during the night at Manchester. If we had exhausted all the store which we had we could have delivered at the rate of 23·6 inches. In Liverpool they could have delivered at the rate of 33·68 inches. In Dublin they could have delivered 24·6. In Loch Katrine they could have delivered at the rate of 50·64; and in Gorbals they could have delivered at the rate of 40·37 inches in the course of a year; that is, with the several amounts of storage, which vary as you will see from the table.

7423. (*Chairman*). That is to say, supposing that the storage had been equal to the fall?—No; taking their storage as it is, which in one case is only 24,000 cubic feet to an acre, and in another case is equal to 52,000 cubic feet to an acre, so that with a smaller storage, everything else being nearly the same, they were only able in the one case to deliver at the rate of 23·6 inches, and in the other at the rate of 40·37 inches; the larger amount of storage by catching the water of wet seasons enabling them to deliver a larger quantity of water. Then I have applied that to the Welsh district which I propose to supply London from; 130,000 acres is the drainage area of that district; the total provision storage is 6,709,000,000 cubic feet; that is equa 51,589 cubic feet of storage for each acre, nearly e to that which is provided at Gorbals, which is largest provision of any of the five places that I l given you above. The drought lasted for 144 da Wales. It really lasted only about 110 or 120 d but putting it on to when the drought broke u other places it makes it 144 days, as against 15 Manchester, 161 in Liverpool, 141 in Dublin, 7 Loch Katrine, and 189 at Gorbals. It is the r almost exactly of Manchester and Liverpool, within three days the same as at Dublin, the being measured at five rain gauges, which are sp over the district, and which show very nearly actual mean rain. The rainfall in the Welsh dis was 9·2 inches; the rainfall at Manchester w inches. Taking the mean rain of all the places M chester, Liverpool, Dublin, Loch Katrine, and Gor it was 10·8 inches. Deducting Liverpool, which s to be an exceptional case, and which certainly does represent anything like the drainage ground of Welsh district, the mean rain was 10⅛ inches. mean produce from each 1,000 acres from all t places, was ·949 of a cubic foot per second, omitting Liverpool for the cause I have before na it was 1·087 cubic feet per second. Therefore in table which the Commissioners have before the have taken the produce of the Welsh district at a c foot per second for each 1,000 acres, which is about the $\frac{5}{100}$th part of a foot per second more the mean of all the districts, and about $\frac{1}{10}$th of a per second less than the mean, omitting Liverp Then allowing for that amount of water comin the ground, we could have supplied 350,000,000 lons of water per day from the Welsh district, w is equal to 41½ inches of rainfall in the year. I summed it up shortly in this table:

METROPOLIS WATER SUPPLY.—WELSH SCHEM

THE drought of 1868 only lasted about 120 days b ning at the end of March and ending early in August assuming it to have lasted for 150 days as in Manche or as the mean of Manchester, Dublin, and Liverpool result would have been as follows:—

The yield of the rain and springs on the average of M chester, Liverpool, Dublin, Loch Katrine, and Gorbals ·949 cubic feet per second from each 1,000 acres. Omit Liverpool as showing an exceptional return, the mean 1·087 cubic feet per second per 1,000 acres.

We may, therefore, assume 1 cubic foot for Wale 540,000 gallons per day from each 1,000 acres of collec ground.

	Gallons per
Rain and springs from 130,000 acres at 540,000 gallons per 1,000 acres per day	70,200,000
Store in reservoirs in the hills 6,709,550,552 cubic feet ÷ 150 days=	279,000,000
	349,200,000
Deduct for compensation to rivers at the rate of 9 ins. of available rain per annum	73,028,000
Leaves for the Metropolis	276,172,000

If the quantity to be stored in the service reservoirs Stanmore, be added viz. 772,500,000 cubic feet, the t storage will be 7,482,000,000 cubic feet and the result be as follows:

	Gallons per
Gross storage in reservoirs, 7,482,000,000 cubic feet ÷ 150 days=	312,000,000
Produce of rain and springs	70,200,000
	382,200,000
Deduct compensation to rivers	73,028,000
Leaves for City for 150 days of drought	309,172,000

Or, taking the supply to the City at 230,000,000 gallons per day, the quantity on which the calculations presented to the Commission have been based, and the compensation to the rivers at 73,000,000 equal together to 303,000,000 gallons per day, there would be left in store at the end of a drought of 150 days 1,117,550,552 cubic feet in the reservoirs in the hills, and 772,500,000 cubic feet in the service reservoirs near Stanmore, together 1,890,000,000 cubic feet. This, allowing for the produce of the streams, is equal to a further provision for a full supply both to the City and to the rivers of 47 days; showing that the scheme as laid out is equal to a provision for 197 days of such a drought as occurred in this year, 1868, being about 50 days longer than it actually lasted.

Taking the Welsh scheme, the drought of 1868 only lasted about 120 days, beginning at the end of March, and ending early in August, but assuming it to have lasted for 150 days as in Manchester (I find that it lasted 144) or as the mean of Manchester, Dublin, and Liverpool, the result would have been as follows: The yield of the rain and the springs on the average of Manchester, Liverpool, Dublin, Loch Katrine, and Gorbals, was ·949 of a cubic foot per second from each 1,000 acres. Omitting Liverpool, as showing an exceptional return, the mean was 1·087 cubic feet per second per 1,000 acres. We may therefore assume one cubic foot for Wales, or 540,000 gallons per day, from each 1,000 acres of collecting ground. The rain and springs from 130,000 acres at 540,000 gallons per 1,000 acres per day, gives 70,200,000 gallons per day. The store in reservoirs would be 6,709,550,552 cubic feet, which, divided by 150 days, gives 279,000,000 gallons per day, making together 349,200,000 gallons per day. Deducting for compensation to rivers at the rate of nine inches of available rain per annum, 73,000,000 gallons, you would have left for the Metropolis during the drought of 1868, according to the provision laid down in the scheme which I have had the honour of presenting to you, 276,000,000 gallons per day, or, taking the supply to the city of 230,000,000 gallons per day the quantity on which the calculations presented to the Commission have been based, and the compensation to the rivers at 73,000,000 equal together to 303,000,000 gallons per day, there would be left in store at the end of a drought of 150 days 1,117,550,552 cubic feet, or 30 days full supply, allowing for the produce of streams making a total provision for 180 days. That is as I laid the scheme before you, when I merely assumed 120, or at most 140 days provision, but it turns out by the experience of the drought of 1868 to be a provision for 180 days of full supply, and this is without including the Stanmore service reservoirs.

J. F. Bateman, Esq.

9 Dec. 1868.

7424. Then we are to understand that supposing a like drought of 150 days should take place, having regard to the provision which you have made in your Welsh scheme, you would still have 30 days supply plus the consumption during the drought?—Yes, left in store, that is to say, the streams would yield, and the storage would give together a full supply for 30 days beyond the 150. If you will be kind enough to turn to my evidence of the 5th of March in this year, at page 6, you will find some calculations as to what I believed I could safely say that the scheme would be equal to, and I was very careful not to overstate that nor to over-estimate anything. You will find that I have only allowed, as the produce of the streams during 120 days or 140 days, 30,000,000 gallons if the drought lasted for 120 days only, and only 25,000,000 gallons per day as the produce of the streams if the drought lasted 140 days. I have shown, I think, upon evidence which cannot be doubted, that instead of its being 30,000,000 or 25,000,000 it would in fact be 70,000,000 throughout 150 days, or probably more than 70,000,000 throughout a drought of 180 days, so that I certainly have under estimated the quantity of water which my district would yield by 35,000,000 or 40,000,000 gallons as the produce of the streams. I merely draw the attention of the Commission to that in order to show that in that case, and in every other I hope, I have been careful not to make an over statement. I will merely supplement my evidence by giving you the rainfall for the first 10 months of 1868, during the droughts which occurred at Loch Katrine and Gorbals, at Manchester, at Liverpool, at Dublin, and in Wales, showing the total amount of rainfall at each of those places, and the rainfall which occurred during the period of drought. (See p. 474.)

I may draw your attention, perhaps, to this. If you take Dublin and Wales the average rain at Dublin was very nearly the average rain in Wales during the period of drought, and almost exactly the average rain in Manchester. In Manchester you will find the rain put down rather less than I have taken it in the evidence which I have given, because those gauges are valley gauges; they do not represent the full amount of rain falling upon the whole of the drainage ground, and I have added a little in order to bring it up to what I believe to be nearly the mean. I will also put in a table of the rainfall in the Snowdonian Range, as it is called, at places not far distant from the district which I have brought under your notice, showing the rainfall of the various places there, and the elevation above the sea.

RAINFALL in the SNOWDONIAN RANGE, 1868.

—	Where— Portmadock.	Blaenydda Festiniog.	Sydun Beddgelert.	Glyn Padarn Llanberis.	Victoria Hotel, Llanberis.	Dinorwic Quarry.	Bethesda, Penrhyn Quarry.	Bethesda Bryderwen.	Bettws-y-coed.	Rhiwbryfdir Slate Company's Quarry.	Bala.	Dolgelly.	Hafodyllan Quarry.	Snowdon Slate Quarry.
	Elevation above Sea.													
	10 ft.	600 ft.	330 ft.	377 ft.	370 ft.	850 ft.	1,000 ft.	500 ft.	70 ft.	1,100 ft.	544 ft.	43 ft.	1,300 ft.	1,500 ft.
January -	6·04	7·17	12·93	9·68	10·39	7·57	6·52	6·18	7·32	12·19	7·78	8·53	8·13	13·98
February -	3·65	6·34	10·26	6·33	5·89	6·04	4·70	5·24	5·35	10·12	4·33	4·91	9·75	9·67
March -	4·77	11·51	12·75	9·71	11·47	8·14	7·12	7·58	8·42	13·38	7·42	7·36	11·98	12·57
April -	2·71	5·37	5·90	4·46	5·23	4·40	2·42	4·02	2·71	5·55	2·29	4·60	3·60	6·47
May -	1·97	3·70	—	4·27	4·11	3·62	2·83	2·21	2·73	4·47	1·72	2·57	—	7·37
June -	0·49	1·02	—	0·59	0·32	0·55	0·69	0·59	0·53	2·02	0·69	0·41	—	1·70
July -	0·78	2·59	—	1·98	1·40	1·87	1·88	1·81	1·98?	2·83	0·45	1·48	—	2·64
August -	4·09	5·65	—	5·15	6·33	5·74	—	—	—	7·81	2·91	5·22	—	10·18
September	2·60	2·62	—	2·68	3·37	2·85	—	—	—	2·73	3·16	3·63	—	5·10
October -	5·42	7·36	—	7·58	—	7·91	—	—	—	15·80	5·15	6·95	—	14·62
Total -	32·52	53·33	41·84	52·43	48·51	48·69	26·16	27·63	28·94	76·90	35·90	45·66	33·46	84·30

The rainfall varies during those 10 months from 32 inches to 84 inches; it is 32 inches at 10 feet above the level of the sea, and 84 inches at 1,500 feet; 77 inches at 1,100 feet, 49 inches at 850 feet, and 52½ inches at 377 feet. This completes all the information which I was anxious to lay before the

RAINFALL in the LOCH KATRINE, MANCHESTER, LIVERPOOL, and WELSH DISTRICTS, for the first 10 Months of 1868, and during the Droughts at the respective Places in 1868.

MONTHS.	GLASGOW CORPORATION WATERWORKS. LOCH KATRINE. Loch Venechar, elevation above Sea 275 ft.	Loch Drunkie, elevation 420 ft.	Bridge of Turk, elevation 270 ft.	Between Glen Finlas and Ben Ledi, elevation 1,300 ft.	At head of Loch Katrine, elevation 380 ft.	On Summit of Hill above Tunnel, elevation 830 ft.	Loch Dhu, elevation 325 ft.	Aberfoyle Inn, elevation 60 ft.	Hills between Loch Ard and Loch Katrine, elevation 1,500 ft.	Duchray Valley, elevation 1,800 ft.	Murdock Reservoir, elevation 320 ft.	GORBALS. Waulk Glen Reservoir elevation 280 ft.	Ryat Linn Reservoir, elevation 310 ft.	At Myddleton, elevation 550 ft.	Nether Cairn Black Loch, elevation 700 ft.	MANCHESTER CORPORATION WATERWORKS. Rhodes Wood, elevation 520 ft.	Wood-head, elevation 680 ft.	LIVERPOOL CORPORATION WATERWORKS. Liverpool Corporation Waterworks, elevation 700 ft.	DUBLIN CORPORATION WATERWORKS. Annacarrier, elevation 750 ft.	Knockatemple, elevation 760 ft.	Tithewer, elevation, 1,000 ft.	Roundwood, elevation 800 ft.	Vartry Lodge, elevation 720 ft.	WALES, SOURCES OF RIVER SEVERN. No. 1, elevation 950 ft.	No. 2, elevation 1,300 ft.	No. 3, elevation 550 ft.	No. 4, elevation 1,100 ft.	No. 5, elevation 720 ft.	No. 6, elevation 2,000 ft.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
January	9·3	10·0	8·2	7·5	17·0	11·8	15·2	10·9	10·3	17·0	8·4	9·25	7·90	9·00	6·40	4·15	4·50	3·01	6·84	5·16	4·46	4·11	5·80	4·6	12·0	8·5	7·0	10·2	6·3
February	6·9	10·5	5·3	5·0	17·4	13·8	12·8	8·1	11.4	12·4	8·3	7·22	6·15	8·60	7·70	4·30	5·50	2·81	3·74	2·89	2·56	3·31	2·63	4·0	13·5	10·5	7·1	4·9	11·3
March	6·3	7·2	5·6	5·6	Observations incorrect.	10·1	10·2	7·7	8·7	9·6	6·2	6·00	5·95	7·50	6·25	6·60	8·58	5·26	3·30	3·49	2·91	4·10	3·64	5·2	7·0	9·0	9·3	17·3	11·4
April	3·9	4·2	4·3	3·5		5·1	5·8	4·4	6·0	4·8	3·1	3·65	3.85	4·30	4·15	3·08	3.84	2·44	3·45	3·33	3·36	3·53	3·52	2·4	4·0	2·5	2·1	4·9	4·9
May	4·3	5·3	4·8	6·3		5·9	6·4	4·5	6·1	6·3	2·8	2·95	3·00	3·60	3·53	1·69	1·60	2·38	2·32	2·48	2·55	2·55	2·63	2·3	1·8	1·1	2·7	3·4	2·2
June	1·7	2·3	1·8	1·8		2·9	3·25	2·7	1·8	5·3	2·0	1·90	1·90	2·60	2·25	0·58	0·42	0·83	2·37	1·60	1·76	1·86	2·00	0·4	1·1	0·6	0·7	0·5	1·0
July	0·9	1·3	1·0	1·2	1·95	1·5	1·65	0·6	0·7	1·6	1·1	0·50	0·50	0·70	1·00	0·68	0·66	0·59	1·53	1·27	1·11	1·53	2·68	1·1	0·5	0·7	1·2	1·1	0·7
August	8·2	9·9	7·9	8·5	12·0	8·6	9·5	8·9	9·0	11·6	4·3	5·15	5·30	5·50	5·50	3·58	3·80	5·35	6·20	4.03	2·32	6·18	6·57	4·4	5·0	2·9	5·1	4·8	6·4
September	2·6	2·8	2·2	5.1	3·6	3·0	3·4	3·0	3·8	4·2	2·8	2·40	2·60	3·15	2·80	3·00	3·30	2·48	9·59	12·16	9·50	10·01	10·54	2·2	3·0	2·8	2·4	3·4	3·2
October	7·6	8·4	7·2	4·6	11·6	10·2	10·9	7·7	10·6	11·6	5·5	5·90	4·70	6·60	5·95	5·92	6·60	7·73	2·69	2.41	1·88	3·17	1·65	6·0	9·5	6·1	7·8	8·6	7·1
	51·7	61·9	48·3	49·1	—	72·9	79·1	58·5	64·4	84·4	44·5	44·92	41·85	51·55	45·53	33·58	38·80	32·88	42·03	38·82	32·41	40·35	41·66	32·6	57·5	44·7	45·4	59·1	54·5
April 28-30	—	—	—	—	—	—	—	—	—	—	—	3·65	3·85	4·30	4·15	0·38	0·39	—	—	—	—	—	—	—	—	—	—	—	—
May	—	—	—	—	—	—	—	—	—	—	—	2·95	3·00	3·60	3·53	1·69	1·60	—	2·32	2·48	2·55	2·55	2·63	2·3	1·9	1·1	2·7	3·4	2·2
June	1·7	2·3	1·8	1·8	—	2·9	3·25	—	1·8	5·3	—	1·90	1·90	2·60	2·25	0·58	0·42	—	2·37	1·60	1·76	1·86	2·00	0·4	1·1	0·6	0·7	0·5	1·0
July	0·9	1·3	1·0	1·2	1·95	1·5	1·65	—	0·7	1·6	—	0·50	0·50	0·70	1·00	0·68	0·66	12·20	1·53	1·27	1·11	1·53	2·68	1·1	0·5	0·7	1·2	1·1	0·7
August	0·9	0·0	0·8	0·5	1·5	0·3	1·2	—	0·5	2·3	—	5·15	5·30	5·50	5·50	3·58	3·80	—	6·20	4·03	2·32	6·18	6·57	4·4	5·0	2·9	5·1	4·8	6·4
September	—	—	—	—	—	—	—	—	—	—	—	2·40	2·60	3·15	2·80	1·16	1·24	—	0·9	0·08	0·21	0·12	0·45	1·2	0·5	0·7	0·2	0·3	0·7
October	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3·5	3·6	3·6	3·5	—	4·7	6·1	—	3·0	9·2	—	16·55	17·15	19·85	19·23	8·07	8·11	12·20	12·51	9·46	7·95	12·24	14·33	9·4	9·0	6·0	9·9	10·1	11·0

The droughts in the respective districts extended as follows:—Loch Katrine, from 30th May to 8th August=70 days; Manchester, from 28th April to 24th September=150 days; Liverpool, from 28th April to 6th October=161 days; and the rainfall given in the Second Table is for these periods at the several places,

Commission upon that subject. There is one other thing which I have prepared if the Commission would like to have it, that is, a table showing the average daily quantity of water supplied by the London water companies during 1866, 1867, and 1868, up to the end of October, showing the increase which has taken place; it is compiled from the Registrar General's returns.

J. F. Bateman, Esq.

9 Dec. 1868.

TABLE, showing the average daily Quantity of Water supplied by the London Water Companies during the Years 1866 and 1867, and the 10 Months ending October 31st 1868, and during the Summer Months of June, July, August, and September in each Year, compiled from the Returns made to the Registrar-General.

Name of Company.	Average daily Supply.			Average daily Supply for the Summer Months of June, July, August, and September.		
	Year 1866.	Year 1867.	10 Months ending Oct. 31, 1868.	Year 1866.	Year 1867.	Year 1868.
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons	Gallons.
Chelsea	7,918,375	8,087,258	8,445,810	8,390,550	8,825,125	9,357,325
West Middlesex	8,236,878	8,816,486	9,016,891	8,894,328	9,443,872	9,870,002
Southwark and Vauxhall	12,679,311	13,629,758	14,572,040	12,902,433	13,970,687	15,248,391
Grand Junction	8,709,089	9,533,432	9,951,684	9,367,220	10,511,205	10,978,497
Lambeth	8,950,566	8,975,533	9,753,920	9,691,775	9,680,825	10,911,075
Total from River Thames	46,494,219	49,042,467	51,740,345	49,246,306	52,431,714	56,365,290
New River	22,931,917	23,790,667	23,740,500	24,636,500	25,927,750	26,111,500
East London	19,321,989	19,298,241	18,249,377	20,702,466	20,094,035	18,450,460
Kent	6,148,562	6,468,873	7,390,418	6,684,885	7,027,292	8,067,642
Total from other sources	48,402,468	49,557,781	49,380,295	52,023,851	53,049,077	52,629,602
Total from all sources	94,896,687	98,600,248	101,120,640	101,270,157	105,480,791	108,994,892
Increase in average daily supply	—	3,703,561	2,520,392	—	4,210,634	3,514,101

TABLE, showing average daily Quantity of Water supplied by the several London Water Companies during the 10 Months ending October 31st, 1868, compiled from the Returns made to the Registrar-General.

1868. Months.	From the River Thames.					From other Sources.			Totals.	
	Chelsea.	West Middlesex.	Southwark and Vauxhall.	Grand Junction.	Lambeth.	New River.	East London.	Kent.		
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	
January	7,408,000	8,149,316	13,983,245	8,733,768	8,078,600	21,884,000	18,052,900	6,438,116	92,727,945	
February	7,378,200	8,068,372	13,984,289	8,816,966	8,401,700	21,647,000	17,834,000	6,630,445	92,760,972	
March	7,453,700	8,282,620	13,935,750	9,034,665	8,615,900	21,094,000	17,822,730	6,858,626	93,097,991	
April	7,610,400	8,541,342	14,115,536	9,185,067	9,200,300	21,331,000	17,828,500	6,987,871	94,800,016	
May	8,661,800	9,347,579	14,468,292	10,328,200	9,736,500	23,937,000	19,120,000	7,779,420	103,378,791	
June	9,333,900	9,663,274	14,994,105	10,830,045	10,607,300	25,486,000	19,950,838	8,177,228	109,042,690	Mean, 108,994,892. Average, 435,979,567.
July	9,748,100	10,665,049	15,178,697	11,121,734	11,210,400	27,140,000	19,900,000	8,299,857	113,263,837	
August	9,317,700	10,014,740	15,410,081	11,417,321	11,046,500	26,869,000	15,848,000	8,065,697	107,989,039	
September	9,029,600	9,136,946	15,410,680	10,544,888	10,780,100	24,951,000	18,103,000	7,727,787	105,684,001	
October	8,516,700	8,299,676	14,239,719	9,504,187	9,861,900	23,066,000	18,033,800	6,939,135	98,461,117	

There is only one observation which I wish to make upon this table, and that is that in 1866 the average quantity supplied by the East London Water Company was 20,702,000 gallons per day; in 1867, 20,094,000; and in 1868, 18,450,000. During the month of August in this year the East London company was only delivering about three-fourths of the quantity of water which it ought to have delivered, owing to absolute scarcity; it was not in the river Lee to deliver. The normal delivery of the company is 19,950,000 gallons in summer, as it was in June and July; but in August it only delivered 15,848,000, in September only 18,100,000, and in October only 18,033,000, so that owing to that deficiency in the water supply the increased consumption of 1868 over 1867 has not been quite as much as it would have been had the East London company been capable of giving a full supply. The increase of 1867 over 1866 was 4,200,000 gallons per day during the months of June, July, August, and September, and upon the whole year 3,700,000 gallons per diem. The increase in 1868 over 1867 in the four months June, July, August, and September was 3,514,000 gallons per diem, but had the East London company been capable of delivering its full quantity, it would have been upon the summer months 4,500,000 gallons per day, and upon the whole year about 3,000,000 gallons per diem.

7425. Then the increase was less in 1868 than in 1867?—Yes, slightly.

7426. Then having regard to the progressive increase of former years, supposing that the supply had been equal to the demand, what would have been the deficiency?—The increase would have been about the same. I have handed in those tables because they bear upon my former evidence, as showing what I estimated to be the increase. Had there been no deficiency in the East London delivery, the figures which I gave before would have corresponded with the facts. I think I have now given the Commission all the information which I wish to lay before them.

7427. (*Mr. Prestwich.*) With regard to the quantity of water supplied to Manchester during the drought of 1868, you stated that the balance left in store on the 25th of September, after 150 days drought, was 435,000,000 gallons, but that during 45 days there was a diminished quantity supplied to the mills, and further, that during 52 days the water was shut off at night. Supposing the supplies to the mills and to the town to have been continued to their full amount during this period, have you calculated what would have been the quantity in store?—We should have exhausted our store, and we should have been perhaps, something like 200,000,000 or 300,000,000 gallons deficient.

J. F. Bateman, Esq.

9 Dec. 1868.

7428. You are preparing larger storage, are you not?—Yes. Our works are now very far from being complete, but we are constructing two new large reservoirs; and we have a third reservoir which we have never been able to fill owing to the bad foundation, which, as soon as the two others are completed, we shall restore, and that will nearly double our storage at once. It is a mere question of storage in Manchester. We have abundance of water, but we are two years behindhand in our works, and we are two years beforehand in the calculated supply. We have been extending the supplies to the outlying districts so much that, while we have been falling behind in our engineering operations, we have been going too fast in the supply of water to the district, and therefore the two causes together put us into this position this year.

7429. How many days storage have you at Manchester now?—The drought lasted 150 days. I think we went on for 105 days without any diminution to the mills, and for 98 days before we shut off the water at night at Manchester, and we had then a very considerable quantity of water in store. Therefore, for something like 120 or 130 days we could have given a full supply to Manchester and to the mills had the drought lasted no longer, but it did last 150 days.

7430. (*Mr. Harrison.*) What are the total cubic contents of your storage at Manchester?—About 2,736,000,000 gallons I believe are the cubic contents of the storage which we now have, and were so at the commencement of the drought of 1868, and we are now increasing it by about 1,800,000,000 gallons.

7431. (*Mr. Prestwich.*) In those diagrams which you have produced showing the delivery of water during the continuance of the drought, the effect of a fall of rain during this period of drought is shown almost immediately is it not by the rise?—Yes.

7432. There were many days, were there not, during which no rain fell at all?—Yes.

7433. Therefore during that period the flow would depend, would it not, entirely upon springs?—Yes, entirely. There is a little variation, but during the whole of June, and down to early in August, the streams were almost wholly spring water.

7434. Therefore this delivery from springs would depend upon the rain which fell during the previous winter?—That would depend upon the geological formation. It would be so if it was upon chalk or sand, but not upon granite.

7435. Or upon millstone grit?—No doubt it does to some extent, but I do not think it does much in the millstone grit, and it does very little in the silurian. The springs fall very quickly indeed in the silurian, and very quickly in the granite.

7435. Therefore the harder the rock surface the less would be the delivery from springs?—Yes, no doubt.

7436. And therefore this delivery would depend very much upon the amount of rain which fell during the preceding winter?—I think not very much. It would, no doubt, depend upon the amount of rain which fell during the preceding period; but you see immediately after rain it falls off very rapidly. The diagram which I have placed before the Commission is a very different one from that which would be shown in a chalk district, or in a sand district, because a chalk district, or a sand district, like the greensands of Surrey, delivers its water out more slowly, and a diagram would not show these sudden rises and falls.

7437. If there was no rain, the supply must have been derived from the rain of the preceding period?—Yes; in the Silurian district of the Dublin waterworks, for instance, which is a district very nearly corresponding with the Welsh district, both geologically and physically, you will find that the produce was 1·3 cubic foot per second from each 1,000 acres during the drought of 141 days. In Loch Katrine, where the springs are almost nothing in dry weather, the ground is not only very steep, but there is only a small portion of flat top covered with peat. The rock is so hard, that in making our tunnels there we had to take water down to lubricate the drill holes for the miners. The water cannot get in, and therefore there is none to come out. During the months of extreme drought, of June and July, the produce of the Loch Katrine district was ·84 of a cubic foot per second from each thousand acres. I had the rivers measured in Wales at the extremity of the drought in July, and the produce there was certainly very small. It was then ·13 of a cubic foot per second. At the extreme of the drought in the millstone grit in the same period the general result was about ·25 or ·3; so that at the extreme drought the silurian district yielded about one-half what the millstone grit did.

7438. Would not that depend almost upon the geological character of the ground, because the harder the rock the less is the delivery, and also upon the inclination?—Yes, unless you go to bare hill sides, where the water comes down as from a roof, and there is nothing to absorb it, and you get every drop of water in the valleys. You have to take it as a compound question; a flat district yields water very slowly, an absorbent district yields it still more slowly. A district composed as Wales, partly of steep hill sides, and partly of gentle undulating slopes, would be equal to the mean between Dublin and Manchester. I think, taking Dublin and Manchester together, the Dublin formation being almost the same as that of the Welsh district, both being Silurian, both being very similarly mountainous, rising to very much the same height, and taking the Manchester district, which rises from 1,900 feet to 2,000 feet, with very steep slopes and flat tops, those afford a very fair sample of the geological and physical conditions of the district forming the source of the Severn.

7439. Do you find in the Manchester district where the water comes from off the millstone grit area, that it gives a larger delivery than the silurian area of Glasgow?—No, it does not, it gives a smaller one than Loch Katrine, for during the 70 days when Loch Katrine was delivering ·839 cubic feet per second, Manchester was delivering only ·5114.

7440. (*Mr. Harrison.*) What was the rainfall during this period?—It was 4·40 inches at Loch Katrine. The drought in Loch Katrine commenced on May the 31st, and ended August the 8th. Therefore it was just through the months of June and July. The mean produce of the district was ·839 of a cubic foot per second from each thousand acres, whereas the mean produce of the Manchester district during the same period was ·5114 only. From the 1st of June to the 28th of June it was ·612, from the 29th of June to the 3d of August, which together cover exactly the same period, it was ·43, and the mean of these is ·56 against ·84, so that the Loch Katrine district really yielded a larger quantity of water than the millstone grit district. The rainfall in Loch Katrine was 4·4 inches, whereas the rainfall in Manchester during that period was only about 1¼ inches.

7441. Can you give us the rainfall for the preceding winter in each of those two districts?—The rainfalls of 1866 and 1867 were both very considerable. I think that the figures will be found in some of the papers which I have put in. In Manchester, in January and February it was about 4½, and about 7½ in March. In Glasgow in some places it was 17 inches in January, 17·4 inches in February, and 10 inches in March, and in Wales it was in February in some parts 10 inches, 12 inches, 13 inches, 11 inches, 17 inches, and in March 11 inches, 9 inches, and 7 inches, so that the Welsh district more nearly approximates to the Loch Katrine district. With regard to a question put to me by Mr. Prestwich I have been working out what was the rainfall during the months of June and July, which was the only period during which the drought extended in the Loch Katrine district, and this was the state of things. In Liverpool in those

months the rainfall was 1·42, at Halifax in the streams to which the diagrams which I have produced refer, it was ·6 of an inch, in Manchester 1·28, in Wales 1·6, in Loch Katrine 4·4, in Dublin 3·54, and I see that in Loch Katrine which is the only one I have worked out as to the exact quantity of water flowing off the ground in those months, in 70 days the produce was equal to 1·39 inches in depth flowing off the ground, so that 3 inches out of $4\frac{1}{2}$ inches were absorbed and lost.

7442. (*Chairman.*) Have you taken any measurements of the Thames this year?—I have had the river measured twice this year in order to get the driest volume. I had it measured in July, but then the river was so full of weeds that it was excessively difficult to get anything like an accurate result, but according to the best approximation that we could make, the volume was about 370,000,000 gallons per day at the same place that I measured at in 1865.

7443. Was the measurement made above the point where the supply is taken by the water companies?— Yes. I had it measured again just after the weather broke in September. I was away from home at the time of the end of the drought, and my people were most of them holiday-making, therefore I did not catch it just at the end of the drought. My impression was that it was never so low as it was in the autumn of 1865.* *J. F. Bateman, Esq.* 9 Dec. 1868.

*16, Great George Street, Westminster,
December 9th 1868.

My dear Sir,

I find that the volume in the river Thames fluctuated so much when I sent to have it measured in September last, from recent rainfall, that the attempt had to be abandoned. In July it measured, as I stated, about 370,000,000 gallons per day, but the river was so choked by weeds that the measurement could not be relied upon as accurate.

Yours very truly,
J. F. Bateman.

W. Pole, Esq.,
Water Supply Commission.

The witness withdrew.

Nathaniel Beardmore, Esq., further examined. *N. Beardmore, Esq.*

7444. (*Chairman.*) You are desirous, are you not, of correcting a table which you put in at the time you gave your former evidence?—There is a slight error in the figures, and therefore I propose to send them in corrected, with the flow and rainfall up to the end of the present year, so as to give the information complete in one view. (*The tables were subsequently sent in by the witness as follows:*)

Estimated Flow of Rivers Lee and Thames.

Mean Annual Flow for 1850 to 1868, including Water Companies' Supply.

Years.	River Lee at Feilde's Weir. Drainage area, 444 square miles.				River Thames at Kingston. Drainage area, 3,670 square miles.				
	Discharge per minute.	Discharge in gallons per day.	Depth run off.	Rainfall at Feilde's Weir.	Discharge per minute.	Discharge in gallons per day.	Depth run off.	Rainfall at Oxford.	Rainfall at Cirencester.
	Cubic Feet.	Millions.	Inches.	Inches.	Cubic Feet.	Millions.	Inches.	Inches.	Inches.
1850	11,176	100·3	6·11	22·22	125,568	1,126·8	7·74	24·2	—
1851	11,800	105·9	6·36	21·90	129,800	1,164·9	8·00	22·0	—
1852	11,892	160·6	9·64	39·50	178,920	1,606·0	11·06	40·4	—
1853	21,762	195·3	11·72	28·75	217,620	1,953·0	12·41	27·2	—
1854	10,335	92·7	5·57	17·85	93,015	834·3	5·73	17·7	—
1855	9,404	84·4	5·06	25·01	94,040	844·0	5·81	25·2	26·10
1856	10,698	95·0	5·78	23·90	128,376	1,140·0	7·91	27·0	32·30
1857	11,942	107·1	6·43	25·36	119,420	1,071·0	7·36	27·5	—
1858	8,615	77·3	4·64	20·86	94,765	850·3	5·84	22·5	25·64
1859	7,818	70·1	4·21	29·24	78,180	701·0	4·82	27·0	28·96
1860	18,462	165·6	9·90	33·75	184,620	1,656·0	11·41	31·1	36·96
1861	14,091	126·4	7·60	20·94	169,092	1,516·8	10·42	23·4	27·39
1862	11,629	104·3	6·26	25·75	139,548	1,251·6	8·60	27·41	32·46
1863	8,594	77·1	4·60	21·97	103,128	925·2	6·37	22·37	27·95
1864	6,811	61·1	3·68	17·88	74,921	672·1	4·63	18·26	24·68
1865	9,768	87·6	5·26	28·79	107,448	963·6	6·62	28·53	35·82
1866	15,480	138·9	8·34	32·25	154,800	1,389·0	9·54	30·67	37·93
1867	14,003	125·6	7·45	25·35	126,027	1,130·4	7·79	27·125	33·70
1868	10,290	92·3	5·47	25·11	108,045	969·2	6·67	25·907	32·68
Means -	12,136	108·8	6·54	25·60	127,755	1,145·5	7·83	26·08	30·97

Mean Flow during the months of June, July, August, and September 1850 to 1868.

1850	7,753	69·5	1·40	7·30	77,530	695·0	1·59	9·9	—
1851	7,346	65·9	1·36	7·40	66,114	593·1	1·36	8·3	—
1852	9,944	89·2	1·79	13·60	99,440	892·0	2·18	17·5	—
1853	14,438	129·5	2·59	10·90	144,380	1,295·0	2·97	11·4	—
1854	6,663	59·5	1·20	4·70	59,697	535·0	1·23	5·1	—
1855	5,476	49·1	0·99	10·30	54,760	491·3	1·13	11·6	11·75
1856	6,839	61·3	1·23	8·20	68,390	613·0	1·40	10·6	10·72
1857	6,512	58·4	1·17	9·00	58,608	525·6	1·20	12·5	—
1858	6,279	56·3	1·13	8·00	62,790	563·0	1·22	8·5	10·09
1859	5,009	44·9	0·90	12·31	45,081	404·1	0·93	12·3	10·31
1860	17,789	159·6	3·20	14·35	160,101	1,436·4	3·30	13·8	16·05
1861	9,189	82·2	1·65	5·30	91,390	822·0	1·81	10·7	10·65
1862	8,550	76·7	1·54	7·77	85,550	767·0	1·76	7·89	12·17
1863	5,684	51·0	1·02	9·62	56,840	510·0	1·17	9·44	12·47
1864	4,744	42·5	0·85	5·73	42,696	382·5	0·88	5·21	7·15
1865	4,812	43·1	0·87	9·11	43,308	387·9	0·89	9·60	11·63
1866	8,386	75·2	1·51	11·75	83,860	752·0	1·74	13·83	17·87
1867	11,575	103·3	1·54	9·26	104,175	929·7	1·84	9·86	10·34
1868	5,209	46·7	·91	6·20	54,694	490·6	1·17	10·12	7·93
Means -	7,481	71·8	1·42	8·99	71,548	688·7	1·46	10·43	11·47

N. Beardmore, Esq.

9 Dec. 1868.

ESTIMATED FLOW OF RIVERS LEE AND THAMES—*cont.*

Mean Flow of June, July, August, and September in the driest Years in the above Table.

Years.	River Lee at Feilde's Weir. Drainage area, 444 square miles.				River Thames at Kingston. Drainage area, 3,670 square miles.				
	Discharge per minute.	Discharge in gallons per day.	Depth run off.	Rainfall at Feilde's Weir.	Discharge per minute.	Discharge in gallons per day.	Depth run off.	Rainfall at Oxford.	Rainfall at Cirencest
	Cubic Feet.	Millions.	Inches.	Inches.	Cubic Feet.	Millions.	Inches.	Inches.	Inches.
1855	5,476	49·1	·99	10·3	54,760	491·3	1·13	11·6	11·75
1859	5,009	44·9	·90	12·3	45,081	404·1	·93	12·3	10·31
1864	4,744	42·5	·85	5·7	42,696	382·1	·88	5·21	7·15
1865	4,812	43·1	·87	9·1	43,308	387·9	·90	9·60	11·63
1868	5,209	46·7	·91	6·2	54,694	490·6	1·13	10·12	7·93
Means -	5,050	45·2	·90	8·7	48,108	431·2	·99	9·77	9·75

7445. Have you anything further to state as to your experience of the river Lee during the year 1868?—1868 has not been such a drought with regard to the chalk rivers as might have been with the intense heat that we had. The heat affected the land springs, and no doubt took them almost away, and in many cases diminished the volume from the springs from the drift above the chalk, but the deep chalk springs have been in very fair volume this year, both on the Lee and on the Thames.

It will be seen by the tables that the heat and drought of 1868 has not reduced the stream to as low a volume as in some other dry years. This is because the chalk springs are too deep to be immediately affected by hot weather, and the supply being mainly governed by the effective flow of the two previous years, both of which were above an average.

7446. Would not the long drought of 1868 require a heavier fall of rain in 1869 to recoup the store in the chalk?—The drought has not been to that excessive degree, for it did not extend beyond the end of July, the rainfall of August, September, and October being rather liberal, so that I think we are insured for next year.*

7447. I mean if this drain were to go on should we not observe in the chalk springs the effect of the drought for some time to come?—Yes, if we have a very dry winter, there may be a low flow next summer; but we have had a full share of rain since August, when the drought broke up.

7448. But you have not had a sufficient fall yet, have you, to make up for the long drought?—I think that the rain of the last day or two will bring us up to a fair supply during the winter; but up to the 5th instant, even when there had been a good deal of heavy rain, the river fell to its normal summer volume within a day or two, owing to the general exhaustion of the water in the upper strata.

7449. Having regard to the amount of rain that has already fallen in the year 1868, is there in your judgment any reason to alter the previous figures which you gave to the Commission as to the net result of the rainfall in the area of the river Lee?—Not at all. I have mentioned in my statement that our real minimum was in 1864, 1865, and 1859, whi were all low years taking the average of the fo summer months. The figures are so near to ea other owing to the large area over which the rs falls. The water has to percolate deep subterrane strata of chalk, and it appears (of course I am spea ing now from 19 years' gaugings) to average itself to a low point at which surface temperature or te porary drought has not much influence. I find th the upper springs fail completely after long d periods; and this reduces the general volume of t river. The lower springs do not vary much in th mean supply; they are very permanent indeed; t the difference of their volume between May a November is frequently very considerable.

The subjoined table of mean flow of June, Ju August, and September, will show that the fl during the minimum period of the year in a riv draining chalk and overlaying tertiaries, is govern by the supply of the previous year and winter. T flow of March and April is here given for comparis with that of the following summer months, and it w be seen that the test of drought has been one or t previous low years; for instance, out of a wh period of 19 years there have been five summers low water supply, viz., 1855, 1859, 1864, 1865, a 1868. According to the deficiency of rain and the he of the summer, the year 1858 should have been l (the whole year's rainfall being only 20·86 inche whereas it had a summer flow of 20 per cent. mo than that of 1868. This is caused by the lar volume of the year 1857, which was carried throu the winter, as will be indicated by the flow of Mar and April of 1858. The low summer of 1858 w followed by a winter so dry as to reduce the flow the following March and April to an extremely lo average for those months. This is one of the fac showing that the period required to fill the subterrane supply to deep springs in the chalk extends over ma months, and that a long period is necessary for the exhaustion.* The summer of 1859, then, is conspicuo as having a small flow both in the Lee and the Thame

* This evidence was given on the 9th December, up to which time the volume of the river had not much increased, but heavy and continuous rains set in on the 15th of the same month which produced heavy floods on the Lee, and still more so on the Thames. The rainfall at Feilde's Weir on the Lee, for December, amounted to 4·80 inches, and at the Radcliffe Observatory, Oxford, to 4·12 inches, which fell during 24 days at each place.

* The summer and autumn of the year 1858 were so dry over the mountainous district of Central Europe that the flow the Danube, the Rhine, the Elbe, the Weser, and other riv was low beyond any precedent. In the Danube foundations an ancient Roman bridge were uncovered that had passed o of memory of man, and was only known of in ancient class records. My friend, Herr Michaelis, Chief Engineer of t Water Staff of Westphalia, informs me that three years elaps from 1857–8 before the deep springs were filled to the norm volume.

ough the rainfall was 12·3 inches; 1864 had a trifle less flow, although the rainfall was only 5·7 inches. The following tables will explain these peculiarities:—

AN SUMMER FLOW of the RIVER LEE, from 1850 o 1868, with the comparative Mean Flow of March nd April in the same Years.

Years.	Mean Flow of June, July, August, and September.	Mean Flow of the previous March and April.	
		March.	April.
	Cubic ft. per minute.	C. ft. per min.	C. ft. per min.
1850	7,753	11,413	15,351
1851	7,346	28,584	15,682
1852	9,944	12,766	6,722
1853	14,438	27,268	24,409
1854	6,633	11,732	9,077
1855	5,476	15,374	6,226
1856	6,839	10,164	9,853
1857	6,512	8,602	13,221
1858	6,279	10,046	14,282
1859	5,009	5,522	6,466
1860	17,789	15,560	12,031
1861	9,139	20,943	17,674
1862	8,550	21,059	20,469
1863	5,684	9,716	8,025
1864	4,744	18,289	8,685
1865	4,812	11,592	7,326
1866	8,386	18,398	16,055
1867	11,575	22,457	14,794
1868	5,209	13,682	10,481
Means -	8,006	15,430	12,465

DETAIL of MEAN MONTHLY FLOW of the RIVER LEE, at FEILDE'S WEIR, including Water Company's Supply for 1868.

Months.	Mean Flow.	Rainfall at Feilde's Weir.	Rainfall at Oxford.	Rainfall at Cirencester.
	Cubic Feet per minute.	Inches.	Inches.	Inches.
January -	23,468	3·50	3·12	4·68
February	16,453	1·65	1·65	2·03
March -	13,482	1·95	1·50	2·56
April -	10,451	1·78	1·54	2·20
May -	7,457	1·40	0·59	1·71
June -	5,766	·20	0·92	0·31
July -	4,726	·20	1·87	0·71
August -	5,211	3·00	3·34	4·02
September	5,133	2·80	3·99	2·89
October -	5,834	2·45	2·24	2·64
November	5,850	1·38	1·01	2·23
December	19,650	4·80	4·12	6·70
Mean -	10,209	25·11	25·91	32·68

7450. Then speaking of the area of the chalk, there nothing in the experience of 1868 seriously to disange the calculations of the water supply?—Not all. It is the other way, it confirms them. I think, in the case of all things in nature extending over ong series of years, we should get practically to a ry close average.

7451. Is there any other point to which you desire to l the attention of the Commission?—No, excepting night observe that the larger the area of such a disct as this, the better you can ensure a water pply.

The Thames has been decidedly giving a good flow s autumn, owing to its very large area, and the cident that in August and September there really as a very considerable amount of rain; viz., in ugust there were 3·34 inches of rain; and in eptember, 3·98. As to the general question of water pply, the practical conclusion I have come to is that, r large cities, it is unsafe to rely upon small areas r a liberal supply of water, especially where the argin for quantity and for due purity should be conderable. Cretaceous and oolite areas have a pre-emient advantage in their springs being deep, whereby mense slowness of filtration is obtained, and so at practically their rivers are the purest when putrection is in highest energy, and when any foul ntributions are at their minimum. During many onths of the hot weather of 1868 no surface flow eached the main body of the Lee or the Thames, the w exceptions being solely due to places where artiial water supply with sewers had been applied. In ct the drought and heat were so great that from une to October all ditches were dried up, and no ain even sufficed to moisten the ditches of the lowest arshes until the 23d of November. The water of ie Lee never showed a trace of turbidity from the 9th of March until the 23d of November, when a fall f nearly an inch of rain on the previous day developed slight trace of turbidity in the water, but up to the th instant—December—no real flood water has own itself.

7452. Is that due to the chalk formation?—I am peaking of rain falling on a large permeable area, lthough the direct effect of that quantity of rain has een but small, yet still it has refreshed the springs, nd the Thames has a very good flow this autumn.

7453. Is that flow of the Thames due to the chalk formation in the upper part?—The upper part of the Thames flows from the oolite, but where you have that formation there is a greater rainfall, so that the flow is supplemented, although you have not got such good storing power. At the Thames head the beds are liable after a drought to lose their water much sooner than the lower beds of the chalk; in fact they are higher springs altogether, and they naturally fall off more.

7454. (*Mr. Prestwich.*) Can you state to the Commission what was the flow of the Lee during the period of drought?—The lowest actual flow of the Lee was in July, and the mean of that month was 4,726 cubic feet per minute.

7455. Can you tell us what rainfall that is equal to?—It amounts to a depth of ·34 inch run off during the month of July, or ·29 cubic feet per second per 1,000 acres. The river Beane where it joins the Lee at Hertford has an area of 71¼ square miles; the flow during the drought of 1868 was ·415 of a cubic foot per second per 1,000 acres.

7456. (*Colonel Harness.*) Do your observations include any records of the position of the water line at different times in the chalk got by gauging wells?—No; I only know this, that on the Lee, whenever we get below 5,500 cubic feet per minute at Feilde's weir, the highest springs begin to fall off.

7457. What is the level of the highest springs in the Lee?—The largest commence above Hatfield, about 180 feet above Trinity high-water mark; below this springs are numerous. One is Woolmer's spring, between Hatfield and Hertford; it is a very beautiful spring, but still it is high, viz., 144 feet above Trinity, and it always fails in low years. It has failed in 1855, 1859, 1863, 1864, 1865, and 1868. The lower and more permanent springs from the chalk are Chadwell, near Ware, at 97 feet; Amwell at 86 feet, and Hoddesdon mill springs at 80 feet above Trinity high water. Below Hoddesdon there is a fault, and the chalk becomes overlaid by the London clay, &c., and there is no water direct from the chalk except by means of borings, which give a good deal of water as far down as Tottenham. The Lee is canalised for a great portion of its length away from the water companies' channels, and it has not been short of water

N. Beardmore, Esq.

9 Dec. 1868.

this year. Mr. Bateman has mentioned something about the East London Waterworks shortening their supply of water; I do not think it can have been owing to the want of water, because we have always had a good head. They have been doing very large work on the Lee, and there may have been some other caus that I do not know of.

The witness withdrew.

J. Taylor, Esq.

JOHN TAYLOR, Esq., examined.

7458. (*Chairman.*) You are a civil engineer, and engaged, are you not, with Mr. Simpson?—Yes, I have been engaged for many years with him. He is engineer to the Chelsea and Lambeth Waterworks Company and he has carried out a large number of other waterworks throughout the kingdom.

7459. You are desirous on his behalf as well as your own, are you not, to put in some documents as to you experience during this last year of 1868 with regard t the rainfall and the condition of your supply?—I hav prepared a table showing the average daily quantit supplied by the metropolitan water companies durin the summer months of the years 1867 and 1868, a follows, which I desire to put in:

RETURN of the AVERAGE DAILY QUANTITY of WATER, in GALLONS, supplied by the METROPOLITAN WATE COMPANIES during the Summer Months of the Years 1867 and 1868.

Companies.	May.	June.	July.	August.	September.	October.
			1867.			
New River	24,772,000	26,326,000	26,710,000	25,617,000	25,058,000	22,474,000
East London	19,207,000	20,060,000	20,321,152	20,192,986	19,802,000	18,948,657
Chelsea	8,360,200	8,814,600	9,042,800	8,875,400	8,567,700	7,875,200
West Middlesex	9,228,482	9,776,707	9,750,965	9,326,213	8,921,602	8,685,121
Southwark and Vauxhall	13,225,000	13,950,000	13,975,000	13,978,000	13,979,750	13,981,340
Grand Junction	9,920,108	10,435,045	11,032,742	10,409,492	10,167,542	9,387,510
Lambeth	9,250,700	9,679,700	10,257,800	9,592,200	9,193,600	8,641,500
Kent	5,901,849	7,179,286	7,196,708	7,039,261	6,693,913	6,600,000
Total	99,865,339	106,221,338	108,287,167	105,030,552	102,384,107	96,593,328
			1868.			
New River	23,937,000	25,486,000	27,140,000	26,869,000	24,951,000	23,066,000
East London	19,120,000	19,950,838	19,900,000	15,848,000	18,103,000	18,033,800
Chelsea	8,661,800	9,333,900	9,748,100	9,317,700	9,029,600	8,516,700
West Middlesex	9,347,579	9,663,274	10,665,049	10,014,740	9,136,946	8,299,676
Southwark and Vauxhall	14,468,292	14,994,105	15,178,697	15,410,081	15,410,680	14,239,719
Grand Junction	10,328,200	10,830,045	11,121,734	11,417,321	10,544,888	9,504,187
Lambeth	9,736,500	10,607,300	11,210,400	11,046,500	10,780,100	9,861,900
Kent	7,779,420	8,177,228	8,299,857	8,065,697	7,727,787	6,939,135
Total	103,378,791	109,042,690	113,263,837	107,989,039	105,684,001	98,461,117
Total average daily supply, 1867	99,865,339	106,221,338	108,287,167	105,030,552	102,384,107	96,593,328
Ditto ditto 1868	103,378,791	109,042,690	113,263,837	107,989,039	105,684,001	98,461,117
Increase in average daily quantity of water supplied in 1868 as compared with 1867	3,513,452	2,821,352	4,976,670	2,958,487	3,299,894	1,867,789
Per cent. of increase	3·52	2·66	4·60	2·82	3·22	1·93

November 1868.

7460. Have you a report made by you to the chairmen and directors of the London water companies?—Yes.

7461. Was that made by the direction of the several water companies of the metropolis, or of the companies of which Mr. Simpson is engineer?—By direction of all the water companies of the metropolis.

7462. Did you make this report to the directors of all the companies?—To the chairmen. The chairmen have formed themselves into a board for the purposes of this inquiry, and they requested me to visit several towns and report the results of gravitation water supplies.

7463. In pursuance of their direction did you visit several towns for the purpose of ascertaining the effect of the short supply of rain during the year 1868 upon the supply of water to those several towns?—I did; and the results of that inquiry are given in a second report. I may state that in May last they requested me to visit various towns in England to procure evidence with reference to the general results of gravitation water supplies in large towns. That I did, and the result of that inquiry is embodied in my first report, dated June the 9th.

7464. But you made a subsequent report, dated November 1868, which would be after the short supply of rain this year?—Yes. Seeing the drought this year, which took place after this first report was made, the chairmen requested me again to go to many towns and ascertain the effect of the drought upon those towns. And the result of that inquiry is embodied in the second report.

7465. Have you any tabulated return which would give the substance of those long reports?—No I have not. I will hand in the first report dated June the 9th, 1868, (*delivering in the same. Vide* Appendix, BB.) I may state that the first report was made on the general appearance of the water supplies by gravitation to towns, anticipating as it were a drought, and foreshadowing what might be the results of a drought of this sort. The results of the drought of this year are given in the report dated November 1868, (*delivering in the same. Vide* Appendix, BC.)

7466. Are those reports the result of your own observation, and of information which you obtained from the several engineers and officers in charge of local works?—They are.

7467. They are made for the purpose of meeting the other schemes which have been proposed?—They are a statement of facts as regards the water supplies to the towns therein mentioned, as far as I could get the facts. I believe them to be substantially correct. I will not be certain that every figure is correct, but substantially it is so.

7468. (*Colonel Harness.*) Are there any facts in these reports which could be disputed by the authorities in those places?—None whatever, to my knowledge. In the second report are given public notices which have been issued referring to the drought and the shutting off of the water in the different towns and the short supplies. Those are public documents, which no one can dispute.

7469. (*Chairman.*) Were your instructions to collect information as to the existing facts? My instructions for the second report were to go round and collect the facts as regards the effects of the drought this year upon those towns.

7470. Without reference to any proposed scheme to supply water to the metropolis?—Yes, without reference to any proposed scheme, but to lay before you the facts with regard to the drought.

7471. And you have given to the directors the results of your experience and observation, and of information obtained from the parties?—I have done so.

7472. Do you also put in a tabular statement of the volume of water in the river Thames measured at various times opposite the Lambeth and Chelsea Water Companies' Works above Kingston?—Yes.

7473. Is that measured at the point where Mr. Simpson has been for some time taking gaugings and has made a careful section of the river?—Yes, it is measured just opposite the Lambeth and Chelsea Waterworks, at the point where they abstract the water. These are the results of the gaugings from time to time as they have been recorded.

7474. And the smallest quantity appears to be 395,000,000 gallons, on the 23d July 1858?—Yes.

TABULAR STATEMENT of the Volume of Water in the River Thames, measured at various times opposite the Lambeth and Chelsea Water Companies' Works above Kingston.

Year.	Month.	Quantity in 24 hours.
1847	October - -	553 millions of gallons.
1852	January 3rd -	602 ,, ,,
1854	September 16th -	413 ,, ,,
,,	,, 18th -	521 ,, ,,
,,	,, 22d -	401 ,, ,,
,,	,, 27th -	418 ,, ,,
,,	,, 28th -	400 ,, ,,
,,	,, 29th -	445 ,, ,,
,,	,, 30th -	425 ,, ,,
,,	October 6th -	436 ,, ,,
,,	,, 24th -	510 ,, ,,
1858	July 23rd - -	*395 ,, ,,
1859	March 23rd - -	*586 ,, ,,
1864	August 2d - -	*370 ,, ,,
,,	,, 16th -	*442 ,, ,,
1868	October 20th -	†554 ,, ,,
,,	November 26th -	†1,400 ,, ,,

4th December 1868.

7475. (*Colonel Harness.*) Between 1854 and 1858, did you change the place of gauging?—It was a little up the river originally, the first ones were above where the Lambeth supply is taken.

7476. Then you went to an intermediate point, below the supply of some of the companies, but above others?—The latter gaugings were taken abreast the lowest of the five companies, which is the Chelsea Company.

7477. Then the last of all is without the whole of the water?—It may be assumed that it is without the water that is taken by the companies.

7478. Will you tell us how you gauged it?—We selected a portion of the river that is pretty straight and equal in the channel, and took a number of cross-sections measuring by a rope the width of the river, and sounding the depths at stated intervals, by which means we get a cross-section of the river, and half a dozen such sections over the portion of the river that we are going to measure are sufficient to obtain an average sectional area, and then ascertaining the velocity of flow of water by experiment and multiplying it into the area, the quantity is arrived at.

7479. (*Chairman.*) Then are the Commission to understand that the table which you have put in is a table shewing the quantity of water flowing past the point where the gauging is taken on the respective days mentioned in this report, and that it is not the minimum flow?—It is the flow at the periods that these were taken at, but they are generally speaking the dry weather flow of the time at which they were taken, excepting the last one.

7480. Do you keep a daily register, or how often are those gaugings taken?—We keep a daily register of the height of the water, and have done so for many years past, but the guagings of the water have only been taken at those periods mentioned.

7481. You have a section and then you have to take the velocity, and that will give you the result?—We take a number of cross-sections and take the mean of those sections; after that we take the velocity of the surface flow, and by a great number of observations we get the mean of that; and then by a certain rule we reduce it to what is called the mean velocity of the river, and multiplying one by the other will give the contents.

7482. Can you tell the minimum flow of the Thames for any given year, taking the year 1867, for example?—No, I have not it for the year 1867. We take the depths, as I stated, daily, but that does not always give the flow.

7483. You may have 1,400,000,000 or 1,500,000,000, or you may have 350,000,000, it depends entirely, does it not, upon when the gaugings were taken?—Yes. But I must explain that these were all taken as the dry weather yield of the year, in which they were made, they were taken at those periods because they were considered dry periods.

7484. Take September 16th, how are we or the readers of your report to understand that the gauging on the 16th of September was not a gauging after a fall of rain on the previous day, or within the previous 48 hours?—I have given them in as the dry weather gaugings, and therefore, of course, that would infer the absence of any considerable rain to affect the river. A considerable fall of rain would immediately produce a very much larger quantity than any of the quantities stated here, excepting the last one.

7485. (*Mr. Harrison.*) Taking the 20th of October 1868, the table shows here a flow of 554,000,000 gallons, is that the smallest flow that has taken place during the whole of the year 1868?—No, it is not. We did not measure the flow during the minimum period. I had no order to measure it, and it was not measured, but I can estimate the flow within very narrow limits during the excessive drought of this year.

7486. (*Colonel Harness.*) From what data would you estimate it?—In the first place we take the depths every day, and they are registered in a book, and from those depths we can always arrive at what the cross-sectional area of the river was at any time, then by the observations of the parties who are daily upon the works I have ascertained that the flow of the stream was somewhere about 5 inches per second.

7487. (*Mr. Harrison.*) That would vary, would it not, with the quantity of water in the river?—I am speaking now of the minimum time which occurred about the end of August and the beginning of

* Exclusive of the quantity abstracted at Hampton by the Grand Junction, West Middlesex, and Southwark and Vauxhall Companies.

† Exclusive of the quantity abstracted by the five Thames Companies.

J. Taylor, Esq.
9 Dec. 1868.

September, that would give 270,000,000 gallons, and from the spot that it was measured at there would be the five companies water which was not included in it.

7488. (*Chairman.*) Can you state what was the minimum flow of the Thames at that point in the years 1866, 1867, and 1868?—I am going to give it in the year 1868, as near as I can estimate it. I cannot give it for the three years, it would be 270,000,000 gallons, apart from about 50,000,000, gallons which the five companies were taking above where the measurement was made, that would be 320,000,000 gallons. That, I believe, is as low as anything that the Thames has been since the companies' works were constructed.

7489. Is that the lowest amount as registered by you?—We have had no measurement so low as that, this is an estimated measurement, and it is the lowest quantity. With regard to the quantity in cubic feet per 1,000 acres, the measurement of the Thames this year, would reduce it down to something like a quarter of a cubic foot per 1,000 acres. I may mention that yesterday I obtained a good deal of information about the River Mole, which supplies a considerable volume of water to the Thames above the Chelsea and Lambeth waterworks. The River Mole has a drainage area of about 130,000 acres, and the minimum flow was reduced to about 20,000,000 gallons from that area, which would be about ·28 of a cubic foot per 1,000 acres. I will also beg to hand in the following table, which I think may be interesting to the Commission:—

TABULAR STATEMENT of the minimum flow of water from various drainage areas.

River.	Year and Season.	Drainage Area. — Acres.	Quantity flowing off per day. — Gallons.	Quantity per 1,000 Acres in Cubic feet
Dee at Woodend (Aberdeen) -	Sept. 1868	332,160	120 millions	·66
Thames at Ditton -	Augt. 1868	2,368,000	320 „	·25
Mole at junction with the Thames -	Augt. 1868	130,000	20 „	·28
Thames at Staines -	Ordinary summer discharge (from Mr. Beardmore's Hydrology.)	1,975,000	360 „	·33
Severn at Stonebench	Do.	250,000	298 „	·22
Lee at Lee Bridge -	Do.	365,000	80 „	·40
* Teith at Deanston -	6th May to 14th Aug. 1826	122,200	34½ „	·52
* Do. - -	June 1826	122,200	20½ „	·30

* See Mr. Bateman's Report 1853, on supply of water to Glasgow, pp. 57, 58, on the drought of 1828.

10th December 1868.

The witness withdrew.

Adjourned to to-morrow at 12 o'clock.

Thursday, 10th December 1868.

PRESENT:

SIR JOHN THWAITES IN THE CHAIR.

Alderman Sir BENJAMIN PHILLIPS.
Colonel HARNESS, C.B.
THOMAS ELLIOT HARRISON, Esq.
JOSEPH PRESTWICH, Esq.

THOMAS HAWKSLEY, Esq., further examined.

T. Hawksley, Esq.
10 Dec. 1868.

7490. (*Chairman.*) The object of the Commission is to ascertain what has been the result of your experience during the year 1868; whether the diminished quantity of rainfall has seriously affected any waterworks with which you are connected, or of which you have any knowledge, and if so, to what extent? Will you have the goodness to furnish us with any information that you have upon the subject?—The diminution in the rainfall has affected the gravitation waterworks very seriously, and the towns which are dependent upon them, but probably not so seriously as the drought of 1865; because the drought of 1868, though more intense, set in at a later period of the summer; and there was this remarkable difference between the two cases, that in the case of the year 1865, I think it was, a great number of the reservoirs had never been filled in the preceding winter; and consequently the drought of the succeeding summer was super-imposed, so to speak, on a drought which continued through a portion of the previous summer, and also to a certain extent through the previous winter. In order to illustrate that part of the subject, that being really the most important one, I produce the diagrams which are kept by the Leicester Waterworks Company of the state of their large storage reservoir, the particulars of which I will shortly give you (*producing some diagrams.*) These diagrams show the state of the reservoir every day. In the latter end of September 1868 the rain returned; but the ground was so dry, in consequence of the long continuance of the drought, that a month ago the rain had not penetrated 18 inches into the ground, and the ground was dusty at a depth of 18 inches, for I have had it opened in various places for the purpose of ascertaining what were the facts. As I say, the ground was as dry and dusty at a depth of 18 inches as you could conceive it to be in the month of July, the rain not having penetrated. And this is the case in various parts of the kingdom where I have tried that experiment.

7491. Have you tried it this month?—I have tried it within a month, but not this month. What I am about to point out is this. In the year 1864 we had in the spring of the year, full reservoirs overflowing and water going to waste to the sea. It then became dry, and the Leicester reservoir descended, as you see by the diagram, till it became almost exhausted, and there was great apprehension that it would be entirely exhausted. This was the year prior to what is called the water famine. I do not suppose that there was more than one tenth of its volume left. These diagrams are kept by the company themselves, and having sent a telegram, I have received them this morning within the last hour; and I thought that they were so important for the purpose of the Commission that I have procured them for you.

7492. Are we to understand that you attribute the deficiency of supply in the year 1865 in a great measure to the small quantity of rain in August, September, October, November, and December of the year 1864?—Yes, and also in January, and part of February 1865. In the next sheet you will see that it continued to descend till the middle of January; then there came some rain, which raised the reservoir a little, but a very little indeed, because it was, so to speak, only like covering the bottom of a wine-glass, so that there was a very little quantity put in. Then it went down again to the end of the month, then there came a flood in February, which raised it with very great rapidity; the flood ceased, and the feed of the reservoir just about balanced the draught upon the reservoir for a week or eight days. Then there came another flood in March, which brought the reservoir up to the point indicated here (*pointing to a diagram*), about 5 feet 8 inches below the overflow. But I ought again to remark upon that, that the quantities of stock in the reservoir are as the cubes of the depths, and therefore that the greater quantity always lies in the upper few feet. The reservoir never filled in that year by a very large amount, and consequently, the drought again setting in, the reservoir was reduced to almost as low as it was in the preceding winter. That reservoir—

and it is important to observe upon that—was made for 240 days storage, and it was nearly exhausted. That is the most important fact which I have to produce; and I have also to state this, that any estimate made upon the duration of a drought, taken from the commencement of the drought to its termination (and I have made that mistake many years ago myself), has been found to be entirely fallacious, because you must add to the drought of the preceding year the number of days of stock which the reservoir fails to fill in the succeeding year, and so on, it may be for two or three years. I dare say there was considerably more than one-third, probably nearly half, the contents of the reservoir contained in its upper portion.

7493. That will depend, will it not, somewhat upon the gathering ground?—Not at all; it is perfectly independent of that.

7494. I mean upon the nature of the springs?—To an insignificant extent—so insignificant that I need not stop to explain it now, but I will explain that very soon.

7495. (*Sir Benjamin Phillips.*) Have the inhabitants any other resources for obtaining water besides this reservoir?—No; but then, as I stated before, this reservoir was made upon the supposition that it ought to contain 240 days of stock. Therefore it never did become exhausted; but it became so nearly exhausted that the company was in great alarm, and notices were put up all over the town, and many means were taken to diminish the waste, and to diminish also the consumption as far as it was possible.

7496. (*Colonel Harness.*) Can you remember what proportion of the average rainfall you have assumed to supply the population?—Put into rainfall I can tell you, but I cannot give it you on the instant. I should say it would be about 9 or 10 inches of the rainfall.

7497. What is the average rainfall?—28 inches, from which we drew off 16 inches, leaving 14.

7498. And you allow 9 inches for your delivery?—Yes, but I should like to be very explicit upon that subject, and to explain the rules which experience has enabled us to come to, and perhaps if the Commission wish to have it now, I may give it at once. We find this from actual experience, that when we make reservoirs of the large capacity which I am about to indicate to you, one-sixth of the whole rainfall goes to the sea; that is to say, the rain continues to come down in wet years when the reservoir is full, and the excess goes over the waste weirs, and of course is lost for ever. I may mention to you that I have for many years been obliged to pay very great attention to this subject, and for my own purposes I have prepared diagrams of the actual facts connected with reservoirs, showing the quantity of water which cannot be retained. First, I will take the case of Greenock, which is a very important case, and gives the result over a great number of years, from 1831 to 1865. I produce that diagram because that is a wet country, and the ground is chiefly whinstone, and therefore is accounted favourable for gravitation works; there is as little loss as may be. The figures on the diagram indicate the inches of rain which fell every year. In those years, namely, the years 1831, 1832, and 1833 to some extent, an enormous quantity of rain fell beyond the average, which could not be stored in the reservoir for use in the succeeding year, for in the next year there was no room scarcely, and you could not put that great area into this little hole (*pointing to the diagram*) to make an average, therefore all that went to the sea and was lost for ever. So the next year the deficiency of gathering was so small when compared with the years of excess, that no reservoir of practical make could have stored that excess; you might write off a little from the top, enough to fill the vacuity, and the rest must have gone to sea.

7499. (*Chairman.*) The years 1836 and 1837 balance each other, do they not?—Yes; the next year is neither sensibly in excess nor defect; the next two years are in defect, but not more than the contents of any reasonably sized reservoir would have supplemented. Then there came an excess, and then in the next year a very serious defect. If the reservoir had been large enough, that excess of former years might have been all stored in order to make good that deficiency, or nearly so. The next year again was near the average, but in the year after, 1844, we come to an enormous defect. The next year that defect was not made good, and the next year again there was another serious defect, and so we go on from time to time. What we find actually is this, that one-sixth of all the rainfall, and we find that from the workings of many reservoirs, is lost. Then in addition to that there is all the evaporation lost. The evaporation here (*pointing to the diagram*) would be about 13 or 14 inches; that would have to be wiped off as a constant quantity from the bottom of the reservoir, and the remainder only is the quantity which is available for the supply. I have also other diagrams for the same place (*producing some other diagrams*) on which you will see marked the quantity lost which could not be stored. The brown part is the quantity which was actually availed of (*describing the same*); 14 inches represent the amount of evaporation which was also lost.

7500. Are we to understand you that 35·91 inches, or nearly 36 inches was actually stored?—Yes, stored and used; it was available for supply, and the loss was the difference.

7501. You have told us the actual net result of the rainfall, can you tell us the average of the rainfall?—The average for the years from 1835 to 1865, inclusive, was 59·89 inches, and the average quantity stored during those years was 35·91 inches; there are many other cases that I might refer to, but the general fact is this, that when a reservoir is proportioned upon the principle which I am about to mention, then the first thing to be done is to ascertain, if it be possible to ascertain it, the average of the rainfall taken over a very large number of years. From that deduct one-sixth, that being the quantity which will inevitably go to the sea and be lost over the waste weir in consequence of excessive rains in wet years, and rain in other years continuing to fall after the reservoir is full.

7502. Supposing the reservoir were made of a capacity equal, or more than equal, to the storing of the whole average quantity of rainfall, would the one-sixth with the same certainty pass over it?—It would not, only such reservoirs are impossible to be made, because the great floods which enter into the average only come once in seven years, or 14 years, or even 20 years. The consequence would be that you would have to make a reservoir which would hold a flood which would happen only once in 20 years, and to make it of a most enormous capacity to distribute it day by day over that 20 years. Now, inasmuch as there are more than 7,000 days in 20 years, you would only get by that daily, which is the object of the supply of water to a town $\frac{1}{7000}$th part of that quantity, whereas the cost of making such a reservoir, even if you could find a situation to do it in, which you could not, would be so enormous that it is utterly impossible to deal with those exceptional cases.

7503. I can understand the objection to making a reservoir of that size, the object of my question was to test the principle, which seems rather an arbitrary one, that one-sixth must necessarily pass off?—It is not abitrary, because it is based upon experience, that experience being reduced to a rule which I think is now so well established that it is impossible to controvert it, which rule I am now about to lay before the Commission. And that being so, with great submission I should rather object to the use of the word arbitrary, because we have ascertained it as a matter of fact. We must have some hard lines, because engineers must proceed upon some data, otherwise calculation would be impossible, and we should all be referred back to what is called judgment, which is the most uncertain guide in the world. The next thing to do is, from the residual quantity to take off the amount of evaporation known to prevail in the districts in hand. It may be a very high and precipitous district, it may be as in the north of England hard ground, or on the other

T. Hawksley, Esq.

10 Dec. 1868.

hand it may be as in the south of England a warmer climate, and flatter land, and so on.

7504. (*Colonel Harness.*) Observations would give you, I presume, the amount of evaporation of a district?—Yes, we know them all, and we can tell with great precision simply by viewing the country what the amount of loss by evaporation is. It amounts rarely to so little as 11 or 12 inches, very commonly upon the hilly grounds it amounts to 13, 14, and 15 inches. In the south of England, and on the flatter grounds and more porous soil, where the water is held superficially, and is then re-evaporated it amounts to 16, 17, and 18 inches. In extreme cases one way it will be as low as 11 or 12 inches, and in extreme cases the other way as high as 18. Upon hilly ground of the character of the watersheds which are used in Lancashire, Yorkshire, and Scotland, where mostly gravitation works are established, the evaporation may at the mean be taken to be 14 inches. At Sheffield we have ascertained it to be very nearly 15 inches, although the ground is very elevated, ascending to 1,500 or 1,600 feet high, but it lies rather with a southern aspect, and the ground is mossy and a good deal of water is held superficially, and of course is re-evaporated without running off or penetrating deep. There we have found that the evaporation is more nearly 15 inches than any other quantity. However, we usually take now for such ground about 14 inches. Then the final result after making those two reductions is the quantity which we hold can be dealt with, and which we know and have ascertained is capable of being dealt with.

7505. (*Chairman.*) Do you mean the waste which runs to the sea and the evaporation?—I mean to say that we first deduct one-sixth, and then the actual amount of evaporation taken off the rainfall leaves the quantity upon which a town may depend, providing the reservoir is made of the large size which is necessary even then to store that quantity.

7506. As to the quantity taken up by absorption by plants and grasses, and every other growing vegetable, that will ultimately find its way, will it not, to your reservoir?—Although it is received into the body of the plant it is given off again by the leaves, and it is taken into the evaporation.

7507. (*Mr. Harrison.*) You include evaporation and absorption generally, do you not?—There is absorption by vegetation but not absorption by the ground, because whatever is absorbed by the ground comes out again in springs, and of course contributes to the reservoir, and whatever that may be it comes out again as part of the water which is stored in the reservoir, and is not to be taken into account. It is an utter fallacy to take that into account separately; it is a part of the quantity of water which is received into the reservoir, which being stored in the reservoir comes in at one end and is given out at the other; and in the cases in which by error the springs have been dealt with as in addition to the reservoir capacity there has necessarily been a failure, because the effect of the reservoir is to store the whole, and if you were to separate the springs and bring them round and deal with them separately, all that you would want would be a larger reservoir which would be capable of adding so much more to those springs as to make up the same average—it makes no difference whatever. Therefore we never in any cases take into account the feed of the reservoir by the springs. Take the Leicester reservoir—there is always water running into it; nevertheless, inasmuch as there is always water going out of it, the final result of the working of the reservoir is that which is indicated upon the diagram.

7508. (*Chairman.*) If I understand you rightly, you first take one-sixth for waste which is now a well-established principle of constructing those reservoirs, and in point of fact, after deducting a sufficient quantity for evaporation, which will include all purposes of evaporation and absorption, you look upon the ground itself as the great reservoir, and what we are in the habit of calling reservoirs are simply mechanical conveniences for the purpose of catching and storing water?—The ground out of which the springs issue is a part of the reservoir.

7509. Do I rightly understand that, taking the metropolitan area for example, or taking the water-shed of the Thames, the evaporation of 12 inches would be a fair allowance?—No, the evaporation in the area of the Thames is 16 inches. There is very little hilly ground in the drainage area of the Thames, and the surface is not hard and the water does not run off.

7510. (*Mr. Harrison.*) You hold in your hand a diagram upon which you say the reservoirs are equal to 240 days supply; do you calculate that supply by the mean cubic contents of the reservoir itself, or do you make allowance for what would be flowing in in the intermediate time in springs?—No allowance whatever for the inflow; it is 240 days, and you require the inflow in addition.

7511. Taking that diagram, you appear there to have had eight months of continually diminishing level in your reservoir. During the whole of that eight months was there no supply either from rain or from springs into the reservoir?—A very considerable supply.

7512. Then the 240 days reservoir had become pretty nearly exhausted, had it not?—Yes, very nearly.

7513. That would almost go to show that in the eight months you would have nearly exhausted the whole of your supply without any supply at all from springs or anywhere else?—The reservoir would have been totally exhausted if there had not been some feed into it; it would have been exhausted a month earlier than the period at which the drought ceased.

7514. (*Chairman.*) In a reservoir of that capacity a foot at the bottom would not be at all equal to a foot at the top?—No, the capacities are as the cubes of the depths, and when we got down near to the bottom, as shown on the diagram, we had not a month's water.

7515. (*Colonel Harness.*) If it had been full it would have contained 240 days' supply, but the deficiency from fulness was more than what you had got from the springs?—Yes. The springs I suppose would give us the difference between the duration of the drought and the capacity of the reservoir. Taking it that the reservoir is empty, for the sake of observation, and that it took nine months to empty it, then, if the reservoir holds eight months storage, we got one month by springs.

7516. (*Sir B. Phillips.*) How long is it since this reservoir was made?—It was made, I think, in 1852.

7517. And you are speaking of 1865?—Yes.

7518. Between the years 1852 and 1865, at any one period, was the reservoir ever known to be as low as it was in 1864—that is to say, as nearly exhausted?—In the year 1864, and again in 1865, it was in the same condition, but antecedent to that it was not so and the reason for that was partly because there had not been the same amount of drought, but it was partly because the full supply had not been given. The company was a new one, and had not got the whole amount of its tenants.

7519. (*Chairman.*) The water line was depressed in 1864, and that accounted, did it not, for the deficiency in 1865?—Yes, that is always the case. A reservoir would be of no value if it was not constructed so as to guard against that contingency.

7520. (*Sir B. Phillips.*) Have you any idea of the nearest approach to the same state of things between 1852 and 1864?—No, I have not, because those diagrams were not kept from the first.

7521. (*Mr. Harrison.*) Have you the result in 1865 in the same reservoir?—Yes (*producing another diagram*). The difference between one and the other when you are at the bottom of the wine-glass, is a mere drop.

7522. (*Sir B. Phillips.*) What is the population of Leicester?—The population is 90,000, and the number supplied is 60,000.

7523. Have you any idea of the quantity supplied per diem to each person?—We supply somewhere

about 1,500,000 gallons per day, or a little under; that is about 24 or 25 gallons in summer (in winter it is less), including that supplied for manufacturing purposes.

7524. (*Mr. Harrison.*) It is singular how nearly the line of decrease is uniform throughout the greater part of the period, although you are getting towards the bottom of the glass?—Yes.

7525. It must have been either by limiting the quantity that they were using in the towns, or you must have had some additional rains?—Yes; rains had come in and helped towards the latter end of the year.

7526. (*Colonel Harness.*) I do not yet quite see why you take away the one-sixth before you take away the evaporation and absorption; because you might find, might you not, that you had got nothing left by adopting that process?—There are cases in which there actually would be nothing left, and those are the cases in the Fens of Lincolnshire, in which there have actually been years when they have had nothing left.

I made a reservoir in Lincolnshire, and the area from which the water is supplied is partly chalk, and very full of springs. The springs ceased to flow on the 1st of May, and they never ran again till the following Christmas Day; and the little flow from the springs at the commencement of the year was the produce of the rain of the preceding year. There are such cases, although they are not frequent. There is another thing which I should like to mention to the Commission, because it is very important. In consequence of these observations, which have now extended over many years, I have had occasion to collect a great number of rainfall tables, and amongst others I have got that of Greenwich for a period of 53 years, from the very commencement of reliable gauging down to the present time, and the mean of the whole is 25·36 inches; but in the year 1864 the rainfall was only 16·8 inches, whilst in the year 1824 the rainfall reached the mean quantity for this neighbourhood of 36·3 inches. With the permission of the Commission I will hand in the following table:—

TABLE of RAINFALL at the Royal Observatory, Greenwich.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total Fall in the Year.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1815	0·9	1·3	2·2	2·7	2·3	1·9	1·8	1·8	1·2	2·6	1·5	2·3	22·5
1816	2·1	1·6	1·9	2·1	2·2	2·4	4·3	2·5	2·1	2·8	3·0	3·1	30·1
1817	3·2	1·3	2·1	0·1	4·6	1·4	4·3	2·7	0·9	2·6	2·0	3·8	29·0
1818	1·9	2·0	3·8	3·3	2·7	0·7	0·8	0·1	4·2	2·1	2·7	1·4	25·7
1819	2·3	3·0	1·8	3·1	3·3	2·5	2·2	0·4	3·4	2·3	3·0	3·8	31·1
1820	1·9	0·6	(1·5)	1·6	4·0	2·3	4·8	1·9	2·4	2·9	2·0	1·8	27·7
1821	2·4	0·04	3·9	2·0	2·4	2·4	3·1	2·1	3·7	2·6	4·7	5·2	34·54
1822	0·6	1·1	1·5	2·9	2·1	0·9	4·5	2·0	1·5	4·0	4·1	2·5	27·7
1823	1·5	3·5	1·5	2·0	0·8	1·2	3·6	3·0	1·0	4·4	1·8	2·8	27·1
1824	1·0	2·5	1·9	2·1	4·2	3·8	2·0	4·4	3·5	2·6	4·3	4·0	*36·3
1825	1·1	1·0	1·4	2·0	3·3	0·8	0·1	2·7	2·8	3·0	3·2	3·2	24·6
1826	0·3	1·9	1·9	1·1	2·7	1·1	2·6	1·9	3·4	1·9	2·8	1·4	23·0
1827	1·2	0·7	2·6	1·3	2·6	0·7	1·4	1·2	3·9	4·4	1·3	3·6	24·9
1828	4·3	1·1	1·0	2·4	1·7	2·2	7·0	4·2	2·6	1·5	1·0	2·5	31·5
1829	0·4	1·3	0·7	4·8	0·6	1·7	4·2	4·5	3·6	1·9	1·4	0·1	25·2
1830	1·7	2·5	0·3	3·2	2·2	2·6	1·9	3·9	3·5	0·8	3·4	1·2	27·2
1831	1·1	3·0	2·2	3·4	1·7	2·1	3·4	2·0	2·2	5·5	2·1	2·1	30·8
1832	1·3	(1·6)	1·4	0·4	1·5	3·3	0·7	3·4	0·4	2·5	1·6	1·2	19·3
1833	1·1	3·6	1·0	1·2	0·2	2·2	1·6	1·8	1·9	1·3	2·3	4·8	23·0
1834	3·2	0·4	0·7	0·5	1·0	1·5	5·3	3·3	0·9	0·4	1·3	1·1	19·6
1835	0·7	2·6	2·5	1·2	3·0	2·4	0·3	1·2	4·2	4·2	2·2	0·4	24·9
1836	1·9	1·8	2·2	2·7	1·3	1·1	1·9	2·6	3·2	4·2	2·4	1·8	27·1
1837	2·6	1·7	0·5	1·3	1·0	1·0	1·5	4·6	1·2	2·5	1·7	1·4	21·0
1838	0·9	2·0	1·0	0·5	1·5	5·1	2·0	0·9	2·9	2·0	3·2	1·8	23·8
1839	1·2	1·5	1·8	1·5	1·6	1·9	3·7	2·7	5·0	1·9	4·4	2·4	29·6
1840	2·4	1·2	0·3	0·1	2·1	1·5	1·7	1·1	2·9	1·7	2·9	0·4	18·3
1841	2·1	1·3	1·3	1·9	2·1	2·7	3·6	2·2	4·0	6·0	3·7	2·4	33·3
1842	1·0	1·1	1·9	0·4	2·1	1·0	3·0	1·8	4·0	1·4	4·2	0·7	22·6
1843	1·4	2·4	0·5	1·7	3·8	1·3	2·4	3·6	0·5	4·3	2·3	0·4	24·6
1844	2·4	2·3	2·9	0·4	0·4	1·8	2·8	2·0	1·2	4·0	4·3	0·4	24·9
1845	2·4	0·9	1·5	0·6	2·2	1·9	1·9	3·1	2·1	1·4	2·4	2·0	22·4
1846	2·8	1·5	0·9	3·1	1·5	0·5	1·5	4·0	1·8	5·1	1·5	1·1	25·3
1847	1·4	1·4	0·8	1·0	1·4	1·5	0·7	2·0	1·6	2·0	2·0	2·0	17·8
1848	1·2	2·6	3·1	3·4	0·4	0·5	2·0	4·3	2·4	3·5	1·2	2·6	30·2
1849	1·6	2·0	0·5	2·2	3·9	0·2	2·9	0·5	3·3	2·7	1·5	2·4	23·9
1850	1·2	1·3	0·3	2·3	2·4	0·9	2·9	1·9	1·3	1·4	2·5	1·2	19·7
1851	2·7	1·2	4·1	2·3	0·8	1·3	4·3	1·5	0·4	1·8	0·6	0·6	21·6
1852	3·6	0·9	0·2	0·5	1·9	4·6	2·3	4·4	3·8	3·8	6·0	2·2	34·2
1853	2·0	0·9	1·5	3·1	1·6	2·8	6·0	2·2	2·4	4·3	1·5	0·7	29·0
1854	1·7	1·0	0·4	0·6	3·3	1·0	1·7	2·9	0·7	2·6	1·4	1·4	18·7
1855	1·0	1·4	1·5	0·1	1·8	0·7	5·0	1·1	1·1	4·9	1·3	1·2	21·1
1856	2·6	1·1	1·1	2·3	3·5	1·6	0·9	2·4	2·8	1·6	1·0	1·3	22·2
1857	2·6	0·2	0·8	1·4	0·6	2·7	1·1	2·6	3·4	4·2	1·3	0·5	21·4
1858	0·8	1·7	0·8	2·3	2·0	1·2	3·0	1·5	0·9	1·4	0·5	1·7	17·8
1859	0·8	0·9	1·4	2·2	2·3	1·4	3·3	1·1	3·8	3·6	2·9	2·2	25·9
1860	1·8	1·1	1·9	1·0	3·9	5·8	2·8	3·7	3·1	1·6	2·5	2·8	32·0
1861	0·55	1·8	2·15	0·8	1·6	1·8	2·1	0·6	1·5	0·9	5·2	1·3	20.3
1862	1·9	0·5	3·7	2·8	2·8	1·8	1·6	3·0	1·6	4·0	1·1	1·7	26.5
1863	2·6	0·6	0·7	0·4	1·2	3·9	0·9	1·8	3·1	1·7	1·8	1·1	19·8
1864	0·9	0·8	2·7	0·7	1·9	0·9	0·3	1·4	2·8	1·1	2·7	0·6	*16·8
1865	3·3	1·9	0·9	0·4	4·2	2·2	2·2	4·0	0·2	6·0	2·4	0·9	28·6
1866	3·5	3·9	1·6	2·4	1·9	3·6	1·6	2·4	3·9	2·0	1·5	1·8	30·1
1867	2·8	1·2	2·3	2·2	2·3	1·8	5·8	2·7	2·9	2·1	0·4	2·0	28·5
1868	4·2	1·3	1·1	2·1	1·7	0·5	1·1	2·6	1·5	2·6	1·2		

	Inches.
* Mean - - - - -	25·36
Calculated min. $\frac{2}{3}$ - - -	16·91
Calculated max. - - -	33·81
Actual min. - - - -	16·8
„ max. - - - -	36·3

T. Hawksley, Esq.

10 Dec. 1868.

This leads me simply to make an observation again upon the averages. If we were to deal with averages we should want to store that 36·3 inches which occurred 40 years previously, and to distribute it so as to come in aid, in point of fact, of the 16·8 inches. For reasons which I have given in part, you could not have stored, by any system of reservoirs which it would be possible to make, that 36·3 inches. I have not yet come to the rule, but we find that by the reservoirs of the great magnitude which I am going to mention, we can store and regulate (for that is the thing wanted) the rainfall of three consecutive dry years—not of the driest years, but of three consecutive dry years. And we find (and it is a very curious fact again, but it comes in justification of what I have already said) that the average rainfall of the three consecutive dry years, taken from any reliable table you please, containing a long series of rainfalls, is exactly one-sixth less than the average of the whole. I give you that as a general law, which within very narrow limits will be found to be true with respect to all rain tables of a reliable character.

7527. And that proves the waste, does it not?—It has nothing to do, for my present purpose, with the waste, but with the capability of storage.

7528. It is the means by which you arrive at the conclusion that one-sixth does pass off to water?—No, it only corroborates it. We arrive at that by actual gaugings upon waste valves and so on, but not in this way; this corroborates it, and I shall make important use of this observation hereafter. But I will, just at the present moment, interrupt myself to state to the Commission what has happened within the last two or three days. I have recently made a very large reservoir based upon the same principles of calculation for the town of Barnsley in Yorkshire, and the water is derived and stored exactly in the same way in which it has been proposed to derive and store water for the use of London. You know that the past summer has been very dry, and as a matter of course that reservoir sank down prodigiously, only a fraction of its full contents was left in the bottom. There have just now come floods. It is a very large reservoir, containing, perhaps, 350,000,000 gallons. That reservoir has been suddenly filled up, and the water continues to run and is now flowing down to the sea in large quantities, and is lost for ever for the supply of the town. There is a practical instance. It was only yesterday, and merely as a report of the fact from the clerk of the works, that I became aware of it. There is a weir there, I think, 60 or 70 feet long, and the water was going 7½ inches deep over that weir after having filled the reservoir in the short time in which it did fill it. That water is gone for ever. It would be quite impracticable to make reservoirs which would store that and all other floods which would be in excess of the ordinary rainfall. Now let me add to that that we shall probably have at all events the usual winter weather; we may have a great deal more wet weather than usual in order to balance the seasons, because they must be balanced some time. Between this period and probably next May that reservoir will be running over, large as it is, and the water will be going into the sea, and will be lost for use. That happens to all reservoirs, and unless the proper deduction be in the first instance made for that quantity which is inevitably lost, the waterworks must fail, and in consequence of that allowance not having been made waterworks have failed. Then I come now to mention to you the rules for the proportioning of the reservoirs, those rules which experience, and experience alone, has been the means of teaching us. We find this, that in wet districts not only does the rain come in greater abundance but it comes more frequently; and in consequence of its coming more frequently we require a less number of days storage to equalize the supply in the manner that I have mentioned, for the supply of a town, and it has been my endeavour over a long course of years to ascertain whether there was any approximate law which could be applied to the determination of the number of days storage requisite in the cases in which the rainfall was 80 inches, perhaps, on the one hand and in the cases in which it was not more than 20 or 22 inches on the other; such, for instance, as in the mountain districts of the north of England very adjacent to the Atlantic on the one hand, and in the flat low districts in the rest of England, the fen districts as an instance, on the other hand, where the rainfall is exceedingly low; and by means of a great number of facts collected over many years, and by pricking them off in a diagram upon a piece of paper, I have been enabled to draw a curve through the prick marks which have fallen up and down, a little above and a little below, and so on, but a curve which would as nearly as possible pass through them. By means of that curve I can find very nearly the number of days' storage which is requisite in different parts of the kingdom where the rainfalls are very different, and it is by that means that I know that in one part of the kingdom the number of days' storage may be, by possibility as low as 150, while in another part of the kingdom it will rise up even to as much as 300.

7529. (*Mr. Harrison.*) You gave us your calculation, did you not, in the particular case of the Welsh scheme, as 170 days?—I estimate that the produce in the case of the Welsh scheme will be, perhaps, about from 24 to 27 inches of rainfall, which would have to be divided, of course, in the usual proportions, that is to say, two-thirds for the service of the town and one-third for the compensation of the stream, those being the usual proportions, and that would give, of course, 16 inches for the service of the town off that watershed. That is the storable quantity; more would fall and then you must take off the quantity which could not be stored in wet years; and that brings me to the observation, that the quantity available for the town would, according to my estimate (but I wish not to have so important a subject merely dependent upon estimate) amount to about 130,000,000 gallons a day. I have no doubt that that is very near the practical result and upon that I wish to make one further important observation, and that is with regard to the small quantity of water which flows off these drainage grounds in dry years. It so happens that for 25 years I have been intimately connected in one way or another with the river Severn. I am concerned for parties in the navigation question. I made the waterworks at Worcester. I was engaged upon the waterworks at Cheltenham and some of the other neighbouring places and we have had to gauge the water actually flowing off. Questions arose which rendered it necessary to gauge the water. There is a weir at Tewkesbury through which the water of nearly 2,000,000 acres of drainage ground passes.

7530. (*Chairman.*) The only point which we are desirous of inquiring into to-day is your experience with regard to the year 1868?—This is an important part of it, because of course the feed into the reservoir is a part of the question of the defects of reservoirs in the year 1868 as well as in other years.

7531. The main point will be this, whether, having regard to the deficient rainfall of this year, the loss of water would be sufficient to cause you to re-examine your previous figures, whether the basis of your calculation may not be interfered with by this exceptional year, or whether there has been sufficient margin taken in all cases of calculation for the reservoir capacity to be equal to the short supply of this year?—By my method it would just cover the short supply of this year, but not by the ordinary method, and not by the method which I myself used in former cases and which was used at that period by all engineers.

7532. Taking credit for, and having regard to, the deductions which you have made from the actual rainfall, and the calculations as to the quantity in store, you believe that, if those calculations were strictly adhered to for this year 1868, the deficient fall of rain of this year 1868 would not interfere generally with your system?—No, it would, as nearly as I can make out, just balance, but not more.

7533. From that fact, that it is just balanced by his special care, would you be inclined to make a greater deduction or to increase your margin, supposing you were laying out new works to-morrow?—I would if I could obtain the money for that purpose. Of course I should always like to retain a reasonable quantity of water at the bottom of the reservoir, not merely as a sort of bank to draw upon to cover mistakes, but because the water which is drawn from the bottom of a reservoir is never in a satisfactory state, and therefore I should always wish to have a few weeks storage left in the reservoir under the worst circumstances, and of course the number of days in those few weeks ought to be added. But that is not all, it very much depends upon how the rainfall is ascertained If the rainfall is not ascertained by a fair distribution, I do not use the word "fair" in an improper sense), of the rain gauges over the whole area, very great mistakes would be made, because if rain gauges are placed in a gorge, or if they are placed on the lee-side of a hill, the quantity of water they will gather is enormous, and any average drawn from those rain gauges would be utterly fallacious. I can give you many remarkable instances, but I want to apply it now in another way, and what I particularly desire to state is this, that in the case of an important project like any for the supply of the metropolis, I am not speaking of a particular project, but anybody's project, it might be my own; but in any project for the supply of the metropolis by gravitation works, the only reasonable way of ascertaining the actual quantity is to put down weirs upon the largest streams, and to attach to those weirs a mechanical instrument of a very simple kind, which shall register upon a piece of paper the height of the water at all times, and the number of hours during which the water flows at that height. Then you can do this, you can not only calculate with perfect precision what water comes off the ground, which is really the only thing to be ascertained, but you can ascertain, by putting it upon a diagram, how much of that water you can store. Because all that you have to do is to make a table, you know the quantity that you will have to draw out, and you assume that you draw out so much a day, and then you put in the quantities which are indicated by that instrument. Then you will find, as completely as if the reservoir was made, how much will go to the sea, how much continues to come at the time the reservoir would be full, and instead of having any vague conclusions you will have a practical fact. If a thing of that kind were set about now, and continued for a considerable number of years, and it were done by the mechanism which I speak of there would be nothing to entertain any doubts about, you would get the facts. All that you would then have to consider would be what size of reservoir you would want to furnish the requisite quantity of water, and what works you would have to make to convey it to London, but at present everything is perfectly vague.

7534. (*Mr. Harrison.*) Has it not been your experience during this season that all the gravitation works have been short generally of their reservoir storage?—Nearly all of them; there are but two or three exceptions in the whole. Leicester is one, and that is because their reservoir is made of so large a comparative magnitude; and Barnsley is another which is made upon that principle.

7535. In the case of Newcastle, they pumped largely from the river, did they not?—Yes, very largely from the river, and for many months certainly they have got a much greater quantity of water from the river than they have got from the drainage area.

7536. As regards their reservoirs, are you aware that even up to last month they were nearly empty?—I have not been there; but having made the works at Sunderland, and having been very much down in the neighbourhood I have heard it and known it as a general statement, but I have not been up to the reservoir.

7537. Have you not seen a report which states that they have determined upon going six miles further off, and are making a very large additional reservoir in consequence of the drought of this year?—I am not aware of that. I have with me the Sheffield rain table, an important table, which I will put in.

The witness delivered in the following table:—

SHEFFIELD WATERWORKS.

RAINFALL AT REDMIRES.

TABLE showing the Three Consecutive Months in each Year which had the Maximum and Minimum fall of Rain.

Year.	Minimum.	Inches.	Maximum.	Inches.	Total Fall per Year. Inches.
1836	April - May - June -	6·275	January - February - March -	†17·160	46·275
1837	March - April - May -	*4·815	October - November - December	12·580	38·625
1838	January - February - March -	6·685	May - June - July -	13·950	40·500
1839	March - April - May -	5·600	July - August - September	†20·905	*49·255
1840	February - March - April -	6·080	September October - November	12·675	40·870
1841	February - March - April -	6·120	May - June - July -	14·555	46·340
1842	April - May - June -	6·270	September October - November	10·410	†33,775
1843	July - August - September	7·730	April - May - June -	15·370	43·645
1844	April - May - June -	*3·650	July - August - September	11·990	†30·145

* Six minimum. † Six maximum.

T. Hawksley, Esq.

10 Dec. 1868.

Year.	Minimum.		Maximum.		Total Fall per Year.	
1845	February - March - April -	7·010	August - September - October -	14·200	45·350	
1846	May - June - July -	8·460	April - May - June -	12·120	39·705	
1847	January - February - March -	6·815	October - November - December -	13·225	39·605	
1848	March - April - May -	8·840	August - September - October -	†17·010	†48·175	
1849	February - March - April -	5·560	October - November - December -	14·445	39·850	
1850	March - April - May -	7·515	July - August - September -	11·405	39·280	
1851	October - November - December -	5·095	May - June - July -	12·850	*34·230	
1852	March - April - May -	*3·265	September October - November -	†17·015	45·900	
1853	February - March - April -	5·230	June - July - August -	12·295	35·790	Minimum, three consecutive years.
1854	March - April - May -	5·000	October - November - December -	14·925	34·400	Observe × 32·99
1855	January - February - March -	5·090	October - November - December -	9·580	28·775	
1856	January - February - March -	7·220	August - September - October -	†17·120	43·155	
1857	October - November - December -	6·520	June July - August -	12·780	36·060	
1858	January - February - March -	*3·710	August - September - October -	12·260	34·810	
1859	January - February - March -	9·895	August - September - October -	†16·285	†46·155	
1860	February - March - April -	8·140	August - September - October -	13·740	44·280	
1861	August - September - October -	6·540	February - March - April -	15·340	37·940	
1862	January - February - March -	8·845	March - April - May -	12·620	40·060	
1863	February - March - April -	*4·470	August - September - October -	14·995	40·700	
1864	June - July - August -	5·710	September October - November -	11·325	*31·880	Minimum, two consecutive years.
1865	May - June - July -	5·830	August - September - October -	12·485	*32·470	
1866	March - April - May -	6·135	June - July - August -	14·440	†47·725	
1867	October - November - December -	7·710	February - March - April -	12·705	38·850	
1868	May - June - July -	*2·235				

* Six minimum. † Six maximum.

The minimum three consecutive years give a mean of only 33 inches = $\frac{1}{6}$ less than the general average.
The lowest year is $\frac{1}{5}$ below the general average.
The highest year is $\frac{1}{4}$ above the general average (usually $\frac{1}{3}$).
The ratio of the highest to the lowest is nearly 49·28 = 7·4, but more usually it is 2·1.
The loss by evaporation is at Sheffield fully 14 inches per annum, and by Mr. Gunson's returns is nearly 15 inches per annum.

The witness withdrew.

Adjourned.

LONDON:
Printed by GEORGE E. EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.

ROYAL COMMISSION ON WATER SUPPLY.

APPENDIX

TO THE

MINUTES OF EVIDENCE,

TOGETHER WITH

MAPS AND PLANS, AND AN INDEX.

Presented to both Houses of Parliament by Command of Her Majesty.

LONDON:
PRINTED BY GEORGE EDWARD EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE.

1869.

CONTENTS.

	Page
ERRATUM - - - - - - - - - -	1
LIST OF APPENDICES - - - - - - - - -	3
APPENDIX - - - - - - - - - -	5
GENERAL INDEX - - - - - - - - -	131
ALPHABETICAL LIST OF WITNESSES - - - - - -	140

ERRATUM.

The following is to be substituted for the corresponding paragraph in Art. 194 of the Report, which contains an accidental error:—

It appears that the sources most free from probable contamination, such as the springs forming the head waters of the Thames, show in 100,000 parts of water, 3,260 parts of "previous sewage contamination," whereas the Thames just below Lechlade contains only 1,270, and after experiencing various fluctuations as it flows by Oxford, Reading, and Windsor, still shows at Hampton only 1,640, or only one-half of that in the head springs of the river. The Kennet above Hungerford contains 830, while just above Reading the quantity is 0. The chalk springs at Amwell give 3,740, while the East London Company's water at London shows 1,077. The water in the Wandle at Mitcham shows less than in the Croydon well.

LIST OF APPENDICES.

PRINTED DOCUMENTS.

	Page
A.—Mr. Pole's Report on the Selection of Samples of Water in the Cumberland and Westmorland Lake Districts	5
B.—Mr. Pole's Report on the Selection of Samples of Water in the District of North Wales	11
C.—Supplement to ditto	15
D.—Drs. Frankland and Odling's Report on the Chemical Quality of the above Samples	15
E.—Reprint of Mr. Bateman's Pamphlet on the Metropolis Water Supply	25
F.—Reprint of Messrs. Hemans and Hassard's Pamphlet on the same subject	35
G.—Letter from Dr. Clark on the Hardness of Water	41
H.—Memorandum by Mr. Bravender on the Upper Part of the Thames Basin	42
I.—Reprint of Mr. Bateman's Pamphlet on Constant Supply	44
K.—Memoranda on the Cost of Pumping and Filtration	48
L.—Returns as to the Capabilities of the Metropolitan Waterworks	48
M.—Details furnished by Mr. Bateman in illustration of his Evidence	50
N.—Statistics of Metropolitan Water Supply in 1866, 1867, and 1868	66
O.—Mr. Pole's Report on the Selection of Samples of Water in the Basin of the Thames	67
P.—Quantities of Water supplied by Metropolitan Water Companies in former Years	70
A F.—Extract from Report of Commission of 1851 on the Chemical Quality of the London Water	73
A G.—Analyses of Metropolitan Waters, by Drs. Letheby and Odling, and Professor Abel, 1867	74
A H.—Report by the same Chemists on the Quality of the Waters, 1868	78
A J.—Examples of the Registrar General's Reports on the London Waters	80
A K.—Letter from Professor Wanklyn on the Quality of the London Waters	95
A M.—Particulars of Water Supplies to various Provincial Towns	97
A X. 1.—Preliminary Report from Drs. Frankland and Odling on the Waters of the Thames Basin	103
A X. 2.—Full Report on ditto	103
A Y.—Mr. Pole's Report on the Collection of further Samples of Water from the Thames Basin	109
B B.—Mr. Taylor's Report on Gravitation Supplies to large Towns	111
B C.—Further Report by him on the Drought of 1868	114
B E.—Supplementary Report by Drs. Frankland and Odling on the Waters of the Thames Basin	119
B F.—Letter from the Engineer of the New River Company	120
B G.—Extracts from Hoffman and Blyth's Analysis of London Waters, 1856	120
B J.—Information from Mr. Taunton as to Gaugings of the Thames at Lechlade, and other Data affecting the Upper Basin of the Thames	125
B L.—Letters on the Deficient Supply of Water in case of Fire, in the Borough of Southwark	129
B M.—Letters from Mr. Hassard and Mr. Symons on the Rainfall in the Lake District during the Drought of 1868	129

MAPS, DRAWINGS, AND DIAGRAMS.

		Page
E. 1.—Mr. Bateman's Project; Map of Aqueduct	*To face page*	35
E. 2.—Ditto; Map of District	„	35
F. 1.—Messrs. Heman and Hassard's Project; Map of District	„	41
F. 2.—Ditto; Line of Aqueduct	„	41
F. 3.—Ditto; Longitudinal Sections of Aqueduct	„	41
F. 4.—Ditto; Transverse Sections of Aqueduct	„	41
Q. 1.—Mr. Dale's Project; Map	„	73
Q. 2.—Ditto; Section	„	73
R.—Diagram of Storage in Liverpool Reservoirs	„	73
S.—Diagram of Kent Waterworks Supply	„	73
T. 1.—Mr. M'Clean's Project; Map	„	73
T. 2.—Ditto; Section	„	73
V.—Mr. Bailey Denton's Plan	„	73
W.—Map of Manchester Waterworks	„	73
X.—Geological Sections near Cirencester	„	73
* Y. 1.—Geological Map of Thames Basin	„	—
* Y. 2.—Contoured Map of ditto	„	—
* Y. 3.—Geological Sections of ditto	„	—
Z.—Mr. Mylne's Project	„	73
A A. 1.—Mr. Fulton's Project; Map of District	„	73
A A. 2.—Ditto; Line of Aqueduct	„	73
A B. 1.—Map and Longitudinal Section of a Part of the Thames	„	73
A B. 2.—Transverse Sections of ditto	„	73
A C.—Mr. Harrison's Diagram of Rainfall and Discharge in Thames Basin	„	73
A D.—Ditto, Diagram of Diminution of Flow in ditto	„	73
A E.—Ditto, Water Level in Chalk	„	73
A L. 1 to 4.—Diagrams illustrating Statistics of the Metropolitan Population	„	97
A N. 1.—Mr. Bateman's Service Reservoirs and Mode of Distribution	„	103
A N. 2.—Ditto, Sections of Reservoirs	„	103
A O.—Glasgow Waterworks; Aqueduct from Loch Katrine	„	103
A P. 1 to 6.—Mr. Bateman's Project; Welsh Reservoirs	„	103
A Q. 1 to 10.—Ditto; Aqueducts	„	103
A R. 1 and 2.—Ditto; ditto	„	103
A S. 1 to 3.—Details for checking Estimates of Lake Scheme	„	103
A T.—Mr. Symons' Rain Gauge Map of Wales	„	103
A V.—Districts and Works of London Water Companies	„	103
A W.—Population and Parish Map of London	„	103
* A Z. 1.—Geological Map of Lake District	„	—
* A Z. 2.—Contoured Map of ditto	„	—
* B A. 1.—Geological Map of Welsh District	„	—
* B A. 2.—Contoured Map of ditto	„	—
B D.—South Staffordshire Waterworks	„	118
B H.—Diagrams of Storage in Halifax Waterworks, 1868	„	124
B K.—Sections of the Thames and Severn, and the Stroudwater Canals	„	128
* B N.—Map of Rivers of England and Wales, with their Catchment Basins	„	—
B O.—Map of Water Supply to various Lancashire Towns	„	130

** The Maps and Drawings marked with an asterisk in the above list are contained in a separate folio.*

APPENDIX.

APPENDIX A.

REPORT on the SELECTION of SAMPLES of WATER in the CUMBERLAND and WESTMORLAND LAKE DISTRICTS.—By WILLIAM POLE, F.R.S., Mem. Inst. C.E. (*This Report is illustrated by the Map, Appendix F.* 1.)

SIR, Westminster, May 29, 1867.

1. I BEG leave to report, that in obedience to the instructions of the Commission, I have visited the lake district of Cumberland and Westmorland, proposed by Messrs. Hemans and Hassard as a source of water supply for London and other large towns.

2. My instructions were, to go over the ground and select points where samples might be taken so as to give a fair idea of the waters of the district; to take such samples and forward them to Dr. Frankland; and to note during the selection any observations that might appear worthy the attention of the Commission.

3. I was furnished with the pamphlet, "On the future Water Supply of London," published by Messrs. Hemans and Hassard, in which their scheme is stated; and I was also favoured with copies of the evidence given by these gentlemen before the Commission.

4. I had a long consultation with Dr. Frankland, and made myself fully acquainted with his views and wishes as to the general mode of selection of the samples; the quantities required; the mode of taking and preserving them; the precautions to be adopted, and so on; all which I have endeavoured to carry out with every possible care.

5. I also had an interview with Mr. Hassard, who gave me useful preliminary information respecting the district, and further explained the views of Mr. Hemans and himself in reference to the water collection.

6. I received information of the sanction of Her Majesty's Treasury to my engagement on the 11th April, and immediately put in hand the necessary preparations for the journey; but the glass carboys to contain the water had to be made specially in Yorkshire, and I could not get them delivered into the district till the 10th May. I have found the collection take more time than I anticipated, from the distances which many of the points lie from places of convenient access, and from the difficulty of transport to and fro.

7. In considering the quality of the water likely to be afforded by any particular gathering ground, it is necessary to notice not only the mineralogical composition of the rocks, but also the nature of the surface of the ground, as regards conformation, covering, and any accidental circumstances that might affect the purity.

8. The rocks in the greater part of this district are such as are usually considered most favourable for preserving the purity of the water falling on them, being practically insoluble, and very little liable to disintegration. I shall note hereafter the places where exceptions to this occur.

9. The conformation of the land is very favourable; the hills rise to a great height, and their slopes are generally steep and rugged, so that the water runs quickly off. This is not only conducive to the purity of the water, from the less time it has to take up foreign matters, but it also tends to diminish the quantity exposed to absorption and evaporation, and so to increase the proportion of rainfall available for storage.

In the upper parts of the ground there is a good deal of bare rock, but the greater part is covered with grass, used for sheep pasture, and sprinkled over here and there with furze bushes.

10. A question has been raised as to the existence of peat moss in various parts of the district. To have investigated this subject specially would have required much longer time and greater expense than I was authorized to devote to my work; and I can therefore only note such facts and impressions as presented themselves during the collection of the samples. I have reason to think that a good deal of moss may exist on the flat places about the hills, and on some of the lower commons and more slightly inclined lands. Names frequently occur on the maps which lead to this inference; for example, there are two "Mosedales," and other names occur in which moss is specially mentioned.

Probably the best test of the existence of moss is the brown colour of the streams in rainy weather. As nearly all my samples were taken in fine weather, they led to no conclusion on the subject; but I found the inhabitants allude frequently to the brown colour of the streams during rain.

The single day's experience I had of somewhat heavy rain, although lasting only a few hours (see notes on samples *B c* and *B d*), confirmed this information, and showed how desirable it will be for the complete investigation of the subject that samples of the water should be taken under different natural conditions.

It has been stated, on good authority, that brown water running from moss becomes blanched by storage in lakes or large reservoirs; and this district might afford an excellent illustration of the fact, if confirmed by careful future observations.

11. Generally speaking, but little of the area proposed to be used for water collection under this scheme is tilled land, or is much inhabited. I shall notice elsewhere the exceptional localities.

In some parts of the district mining operations are carried on, and these deserve serious consideration; I shall mention them fully in the proper places.

I am not aware of the existence of any manufactories within the proposed area, or of any other circumstances calculated to deteriorate the quality of the water.

12. In fixing on appropriate points for the selection of the samples, it has been necessary to have reference to the somewhat complicated arrangement of the several distinct drainage grounds comprised in Messrs. Hemans and Hassard's scheme. This arrangement, I understand, to be as follows:—

To the north of the great dividing range of hills running east and west between Scaw and Shap fells, lie the three lakes, Thirlmere, Ullswater, and Haweswater. They are all at considerable heights above the sea, but the first and third are much above the level of the centre and largest one, Ullswater.

It is proposed to raise still further the levels of these two higher lakes, by damming up their outlets; and also to increase the quantity of water running into them, by adding the drainage from the sides of neighbouring hills, to be collected and brought into the lakes by intercepting conduits at proper levels.

The waters from these two lakes will then be conducted by large conduits into the centre or lower lake, Ullswater, which will be treated as a great distributing reservoir from which the supply will be drawn off as required. This lake has a large drainage of its own, and it is intended to increase it by a small additional district in the same way as the others.

The natural outlet of the Ullswater lake is at the north end, by the river Eamont, flowing into the Eden, and so by Carlisle into the sea. It is proposed, however, in connexion with the present scheme, to tap the lake also at its southern end, and to run water off from it by a tunnel to be formed under Kirkstone pass, and a conduit carried round the slopes of the hills above Windermere, and so away southward.

Provision is also made for intercepting, at a future time, if necessary, further drainage on the south side of the great dividing range, and adding it to the eduction conduit on its way.

13. Having this arrangement in view, I have classified the samples of water as follows, according to the various divisions of the collecting area:—

A. Thirlmere proper.
B. Drainage to be added to Thirlmere.
C. Haweswater proper.
D. Drainage to be added to Haweswater.
E. Drainage of the Lower Lowther.
F. Ullswater proper.
G. Drainage to be added to Ullswater.
H. Additional drainage to be collected, if necessary, on the southern slopes of the main dividing range of hills.

14. At the desire of Dr. Frankland the more important samples have been taken in quantities of eight gallons each, the subordinate or less important ones in quantities of two gallons.

A list of the samples is appended to this report, and the places where they were taken are indicated approximately by red circles on the accompanying small map. But in case it should be important to know the localities more exactly, I have taken care to register the exact points on a copy of the large ordnance map (scale six inches to a mile) which I had with me.

15. It may be desirable I should state the precautions adopted in regard to the samples.

They were collected in glass carboys, holding two gallons each, encased in wickerwork, and provided with well ground glass stoppers. These vessels were all perfectly new, and made expressly for the purpose by the Aire and Calder Glass Bottle Company.

In taking the water, each bottle was cleaned round the neck and stopper, next rinsed three times with the water it was to contain (never less than a quart) and then filled to within a short distance of the stopper. This was fastened down with leather and sealed, and the leather covered with canvas, a record being kept of the number of the bottle, the exact locality, and the attendant circumstances.

From the lakes, where possible, the water was taken by going off in a boat to deep water, and immersing the bottles below the surface. In the streams, places were chosen as free as possible from any risk of accidental impurity, and the water was ladled from the running stream with a ladle of ebonite or "hard india rubber" (a material recommended by Dr. Frankland) attached to a long handle, and was poured into the bottle through a funnel of the same material.

16. I have appended to this report a brief journal of the weather. It will show that, with the exception of one day, all the samples were taken during fine weather, and I think they may fairly represent the fine weather drainage of the district.

17. I made a very rough attempt to estimate the quantity delivered by each stream at the time of my taking it, but I did not attach much importance to this, knowing how very fallacious isolated gaugings would be in such a country, even if much more accurately taken than I had the opportunity of doing.

The smaller streams were running from 1 or 2 to 5 millions of gallons per day, and the general discharge appeared to be from half a million to one million gallons per day for each square mile, or say about $\frac{1}{20}$ of an inch depth per day.

18. I will now proceed to describe in detail the circumstances under which the various samples were taken.

A.

Thirlmere proper.

19. The district naturally draining into this lake has an area of about 13 square miles.

20. The whole of the district is composed of low members of the Cambrian system, called by Mr. Ruthven, "Green slates," having occasional dykes of porphyry and other igneous rocks, and containing some mineral veins.

The surface is very steep and rugged, formed either of bare rock or grass, and is almost uninhabited. It appears to be naturally of the most favourable character for the collection of pure water.

21. It is proposed to raise the level of the lake 64 feet. I see no difficulty in this measure; the outlet being a narrow gorge which could be easily dammed up. A good deal of land would be covered and some few buildings would be destroyed, but the compensation for these would probably not be very heavy. The road also under Helvellyn (leading from Keswick to Grasmere, and much frequented) must be raised where it descends near the lake level, but this would not be very expensive, and the road itself would be improved by the change.

22. I have considered it sufficient to take two samples of the water of this district, one from the lake itself, and the other from the principal stream running into it.

Sample A a. Thirlmere.

23. This sample is of eight gallons, contained in four bottles, Nos. 12, 55, 59, and 60, and was taken on the 13th May.

I should have preferred taking the water from the middle of the lake, but there are no public boats upon it, and the use of the private one, belonging to Mr. Lees, was refused me.

I therefore took the water out of the strong current flowing under the wood bridges between the two portions of the lake, and have no doubt it will fairly represent the general contents.

24. The water was beautifully transparent and colourless, and the small submerged pebbles were quite clear and free from vegetation, which is, I believe, generally considered a sign of freedom from mossy contents in the water. The temperature was 12° Cent.

Sample A b. Main feeder to Thirlmere.

25. This is a two-gallon specimen, bottle No. 40, taken on the 13th May. Snow had fallen on the high hills the evening before.

26. It was taken from the main feeder running into the south end of the lake (consisting of the Wythburn beck combined with the gill from Harrop tarn and others) at a point below the junction of the streams, and about 600 yards above the lake.

27. The water was very clear and colourless. Temperature about 11° Cent.

Leadworks in Thirlmere District.

28. Mr. Hassard has mentioned leadworks in this district, and I thought it right to look at them. They are situated on the steep slope of Helvellyn, forming the east side of the drainage ground.

Levels are driven, at several different places, into the rock, and the mineral is brought down to a point a few hundreds of feet above the lake, where the crushing and washing processes are performed.

The mineral consists, I believe, of the usual "galena," combined with a matrix of quartz and slaty rock, and calcareous and barytic spar. The preparation consists first of crushing the mineral between rollers, and then sorting it by various contrivances in which gravity is the agent, so that the heaviest portions, forming the lead ore, are separated from the lighter or earthy ones.

The material is constantly washed during the process, and the water which runs away carries with it a great quantity of solid matter, and is much fouled.

29. I brought away a two-gallon sample (*A c.* bottle No. 47) of this water, taken on the 13th May, from a point in the stream a few yards before entering the lake.

30. These lead works are already large, and they are increasing in importance; the levels in the hill are extending, and additions are being made to the machinery. They therefore deserve consideration, as affecting the water supply, and I shall make further remarks on the subject in speaking of the Ullswater district.

B.

Additional Drainage to be artificially conducted to Thirlmere.

31. The area draining naturally into Thirlmere being but small, it is proposed to increase it by artificially conducting to the lake the drainage of certain other adjoining districts, viz.:—

1. A portion to the west and north-west of Thirlmere, containing about five square miles.
2. A portion to the north-east, containing about 21 square miles.
3. A portion on the south above Grasmere, about six square miles.

B 1. Western and North-western Addition to Thirlmere.

32. The hills separating Thirlmere from Derwentwater and Borrowdale are said to receive a very large rainfall, and it is proposed to utilize some portions of the western slopes, to the extent of about five square miles, by diverting their waters into Thirlmere.

A portion of the drainage from the western side of Cold Barrow fell, including the little mountain lake called Blea tarn, is passed by a short tunnel through the ridge, direct into Thirlmere. A catchwater drain is then run along the hill side above Derwentwater, and passing round Bleaberry fell is turned downwards to the east and introduced into the north end of Thirlmere. This intercepting conduit also collects in its way the waters of a considerable stream called Naddle beck, which at present runs northwards in a valley of its own, and enters the Greta a little below St. John's beck.

33. The whole of the district thus appropriated is excellent gathering ground; its geological formation is the same as described for Thirlmere, and its surface is entirely rugged steep rock, either bare or covered with spare grass.

The following two samples will, I believe, fairly represent its waters:—

Sample B a. Watendlath tarn.

34. The water that runs through this mountain tarn is supplied from the upper part of Cold Barrow fell, and affords a good example of the drainage of the high western slopes of the hills separating Thirlmere from Borrowdale.

The sample, two gallons, bottle No. 51, was taken 14th May, from the outlet of the tarn above the little village. The water was clear and colourless, but there was a little tendency to vegetation on the pebbles. Temperature, 12½° Cent.

Sample B b. Naddle beck.

35. This stream gives a good example of the drainage running from the north-western parts of this district.

The sample, two gallons, bottle No. 53, was taken on the morning of the 13th May. Snow had fallen on the high hills the night previous. Temperature of stream 8° Cent.

The place was about 130 yards above the crossing of the road from Keswick to Grasmere.

The water was quite clear and colourless.

B 2. North-Eastern Addition to Thirlmere.

36. This addition is proposed to be effected by forming an intercepting culvert to catch the Barrow beck, the Trout beck, the Mosedale beck, and the general lateral drainage falling into the south side of the river Glendermackin; and also the Helvellyn gill, running into the St. John's stream, a little below the outlet of the lake. These various streams are to be led southwards, by the intercepting culvert before mentioned, and to be turned into Thirlmere, at a proper altitude to correspond with its raised level.

37. This is an extensive district, being about 21 square miles; its geological structure is the same as Thirlmere, but it has considerable variety in its superficial character. I have selected three streams for samples, viz., Trout beck, Mosedale beck, and Helvellyn gill.

Samples B c. Trout beck (Greta).

38. There are two streams in the lake district, both having the name "Trout beck," one falling into the Greta, the other into Windermere.

The Greta Trout beck drains at its higher portion the steep and rugged sides of the Great Dodd, the Wolf's Crags, &c.; but it also collects, at a lower level, the water from the flatter slopes of Matterdale common, comprising, I believe, much peat moss. I had no occasion to go over this district, but I was told that portions of it were being drained and cultivated, and the existence of a manufactory of drain tiles at Trout beck station gives some support to the information.

I have two samples from this beck, one taken on the 11th of May (rainy), the other on the 15th (fine and cold).

39. The latter, a two-gallon sample, bottle No. 49, represents, I should think, about the ordinary fine weather condition of the brook; it was taken at the bend above the ford, near the railway station.

The stream was transparent, but very slightly tinged with brown, and had a little white scum here and there; the sunk pebbles had a good deal of vegetation on them. Temperature 7½°.

40. The other sample, two gallons, bottle No. 57, was taken at the bend near Moor end, and about half a mile above the junction with the Glendermackin. This is a mile lower down than the other sample, but there is no accession of water or change of any importance in the interval.

41. This sample was, however, obtained under very different circumstances, shortly after some heavy showers. The beck was changed from a quiet brook to a large rapid river, and the water instead of being clear and colourless, had become turbid and dirty, and of a deep brown colour, with much frothy scum.

Sample B d. Mosedale beck.

42. This is also a two-gallon sample, No. 58, taken about 20 or 30 yards above the railway viaduct, on the 11th May, under the same circumstances as the flood sample of the Trout beck.

43. The drainage ground of this is very similar to that of the Trout beck last described, and the stream was in a similar condition, being much swollen, and delivering nearly the same quantity.

The water was as brown, but I think rather less turbid.

The river Greta was much enlarged and coloured at Keswick the day these two flood samples were taken, but in a few days it had subsided to its ordinary fine weather condition.

44. The two last samples give some idea of the great variations which take place in the character of the drainage of the district under changes of weather. But this idea is only very limited and partial, for the changes here recorded were only the result of a single morning's heavy showers, and cannot approach what must take place under a steady continuance of the heavy rain that this district is celebrated for. It was evident by the appearance of the stream channels that they were often subject to very much larger increase than took place under this temporary flush.

45. It would not be right to draw from the isolated flood samples any inferences as to the suitability of the water for being utilized in the proposed scheme, but if it should be found by further investigation that the moss or the cultivation, or both, render these streams unsuitable, it would not be difficult to separate the waters of the upper or rocky district from those of the common, turning the former into Thirlmere, and making use of the latter for compensation, impounding them in the compensation reservoir proposed to be made in St. John's valley. If the loss of this drainage ground to the general scheme was considered of importance, it would be possible, I should think, to add other gathering ground of a more unexceptionable character on the slopes of the Skiddaw group of mountains to the north of the Greta and the Glendermackin.

46. Other important inferences result from this comparison as affecting the artificial intercepting conduits proposed to be made for collecting the drainage of outlying districts, and conveying it to the storage grounds. If these conduits are to be effective in collecting all the available water, they must be of most ample carrying capacity, and most substantially constructed. And as, independently of this, the ground over which they have to pass is often very rugged and irregular, their cost must necessarily form a large item in the estimate of expenditure.

Sample B e. Helvellyn or How gill.

47. This is an important stream which runs down from the west side of Helvellyn, and would appear at first sight to belong naturally to the drainage of Thirlmere, but it is cut off from the lake by a low longitudinal ridge, and runs, united with other streams, northwards in a little valley of its own, uniting with the St. John's beck about half a mile below its issue from the lake. It is proposed to intercept this and other neighbouring streams, and to turn them into Thirlmere.

48. The gathering ground for this stream is unexceptionable, being almost entirely the steep slopes of Helvellyn.

49. The sample, two gallons, bottle No. 46, was taken 13th May, at a point just above the crossing of the main road.

The water was very transparent and colourless. Temperature 8°.

B 3. Southern Addition to Thirlmere.

50. It is further proposed to add to Thirlmere certain waters falling on the upper portions of the slopes to the south of the ridge dividing Cumberland from Westmoreland, and which now drain into Grasmere.

For this purpose it is proposed to form a conduit, which will intercept at the proper level the river Rothay, and the Easedale beck and other streams running into it, and to convey the combined waters through a tunnel formed under Dunmail Raise northwards into Thirlmere.

51. This will add about six square miles of land, receiving, I believe, a large quantity of rain. The geological and physical features of the ground are the same as described for Thirlmere, and the water is therefore likely to be of the same quality.

Sample B f. Upper Rothay.

52. The sample, eight gallons, bottles Nos. 14, 16, 19, and 33, was taken, 22nd May, from the river Rothay, above the village of Grasmere, and a little below the junction of the Easedale beck.

The stream was clear and colourless, with vegetation on the pebbles. Temperature 11½°.

C.

Haweswater proper.

53. The area at present naturally draining into Haweswater is about 12 square miles.

54. The geological formation is the same as described for Thirlmere, viz., entirely "green slates and porphyry."

55. The physical features of the ground are also very similar, namely, steep and rugged slopes. The surface consists generally either of bare rock or grass, but the eastern slope of the lake is covered with trees.

56. It is proposed to raise the level of the lake 42 feet by a dam at the outlet. This will be quite feasible, as the valley is narrow at that place. It will involve some expense for land and buildings, and for diversion of the road, &c., all which, no doubt, has been taken into account.

57. I have taken two samples of the water of this district; one from the lake itself, and the other from one of its principal feeders.

Sample C a. Haweswater.

58. This is eight gallons, contained in four bottles, Nos. 34, 43, 44, and 50.

It was taken on the 16th May from the lake itself, about 50 yards off the Earl of Lonsdale's boathouse, one of his lordship's boats being courteously placed at my disposal by his steward. Temperature 12°.

Sample C b. Measand beck.

59. This is one of the principal tributaries to Haweswater. It runs from a steep lateral valley, and forms in its lower portion almost a constant succession of waterfalls.

The sample, two gallons, bottle No. 52, was taken on the 16th May at a point immediately above Measand Hall.

The water was clear and colourless, but some persons standing by said, "It came from moss, and that there was better water elsewhere which came over fells."

D.

Drainage to be artificially added to Haweswater.

60. It is proposed to make two intercepting conduits to collect the waters of several portions of land now draining directly into the Lowther, and to turn them into Haweswater.

The conduit to the north will take Heltondale beck, Gill beck, Hews beck, and several smaller ones.

That to the south will begin with the High Lowther at Coopers Green, and will also take the large stream in Swindale and the Naddle beck close adjoining the lake.

61. It is proposed to relieve a part of this latter conduit by forming an auxiliary reservoir in Swindale, as shown on the map.

62. These operations will add about 26 miles to the area draining into the lake.

The ground, as far as I could see it, appears to be of the same character as that round the lake, and I should think the water would be of equally good quality.

I have only thought it necessary to take one sample.

Sample D. Upper Lowther.

63. Two gallons, bottle No. 37. It was taken on the afternoon of 16th May, from a point about 50 yards above Rossgill bridge, and a little below the junction of the Swindale stream with the Lowther. This point is about a mile below where the Swindale beck is proposed to be taken, and about three miles below the place where the conduit is to intercept the Lowther. It may therefore probably be a little less pure. The water was clear and white; but there was much vegetation on the pebbles. Temperature 15°.

E.

Drainage of the Lower Lowther.

64. Independently of the Upper Lowther and its high tributaries, described in the two foregoing sections, it is also proposed to make use of a drainage area of about 22 square miles on the lower part of the same river, extending from the intercepting conduits before named, down to a point about 1½ miles below Askham.

65. This tract of country is of quite a different character, in many points of view, from those previously described.

The greater portion of it is on the mountain limestone formation; the character of the surface is generally flatter, and, lying at a lower level, it is more cultivated and fertile, and more populous, containing many villages. It is plentifully interspersed with trees, Lowther park being entirely comprehended within this area.

66. This appears to me to be a less favourable district for water-bearing than the higher grounds C and D. The water would be likely to be harder, flowing over the limestone, and the drainage from the cultivated lands would give it greater organic impurity.

67. According, however, to the scheme proposed, as I understand it, this drainage becomes inseparably mixed up with those of the higher grounds. It is proposed to allow the water from Haweswater to run down its present course, namely, into the Lowther, and to tap this river at a point below Askham, and convey a portion of its waters by an artificial conduit into the north end of Ullswater.

68. I am aware that Mr. Hassard proposes, on account of the probable inferior quality of this water, to make arrangements for devoting it chiefly to compensation; but it appears to me that if the water in the upper Haweswater district is as good as I believe it to be, it would be a pity not to make use of it as a permanent addition to the general supply, and I think means might be contrived to do this. Possibly a small tunnel (four miles long) direct from Haweswater into Ullswater would not cost much more than the larger conduit (five miles long with one mile in tunnel) proposed to be made from the Lowther to Pooley Bridge, and it would certainly better repay its expense. This Lower Lowther district might then be left to its natural drainage; but the river would be regulated and its floods stopped; and if compensation was wanted in dry seasons, it could be afforded from Haweswater or Swindale.

69. It is not possible to get any satisfactory samples from this drainage separately; all I could do was to take one at or near the point below Askham, where it is proposed to tap the Lowther, this sample therefore representing the whole present drainage of the district above.

Sample E. Lower Lowther.

70. The sample was eight gallons, bottles Nos. 13, 29, 39, 41. It was taken, 15th May, from a point close to Low Gurdon bridge, in Lowther park.

The stream was 60 feet wide by about 18 inches deep, running about 45 to 50 millions of gallons per day. The water was clear and colourless, with a good deal of vegetation on the pebbles. Temperature 10°.

F.

Ullswater proper.

71. The natural drainage area of Ullswater is about 60 square miles. It lies in the "green slate and porphyry" formation, with the exception of a small part at the north-western end of the lake, which consists of the coarse conglomerates of the old red sandstone.

72. The surface is remarkably favourable for gathering ground. The lake is surrounded by mountains rising to between 2,000 and 3,000 feet above its surface, and whose steep slopes are either bare rock or covered with grass, with here and there patches of moss or bunches of furze. On the immediate edges of the lake are many plantations and ornamental grounds.

73. It is proposed to raise the lake five feet, but it would be impossible to tell the influence of this on the property and lands on the banks, without a minutely detailed survey.

74. I have taken samples of water from the lake itself, and from several of its tributary streams.

Sample F a. Ullswater.

75. This is eight gallons, bottles Nos. 1, 3, 4, 5. It was taken on the 21st of May, by means of a boat, from the lake itself near Pooley Bridge. The water was very clear, and its temperature about 9½° Cent.

76. The lake was said to be rather low. I endeavoured to estimate the quantity of water running out at Pooley Bridge, and made it between 35 and 40 millions of gallons per day; but the high wind blowing on the stream rendered the determination of the velocity very difficult and uncertain.

Sample F b. Airy beck.

77. This is one of the largest tributaries to the lake, running in about the middle of the western side. The sample, two gallons, bottle No. 56, was taken on the 17th May, a little above the crossing of the road. There was a little partial and light rain, and I believe the brook was running rather full. The water was clear, but with a slight tinge of brown.

78. *F e.* and *F f.* are other samples of feeders to Ullswater, which will be mentioned hereafter.

There are some large tributaries running into the east side from Martindale, but as the drainage ground of these is so obviously of the same character as the others, I did not think it necessary to take further samples. It is proposed to make auxiliary reservoirs in two of these valleys, which I have no doubt may be easily done.

Lead Workings in the Ullswater District.

79. I have mentioned lead workings in the Thirlmere district, but they assume much greater importance here.

On the east slope of Helvellyn, a little way up the Glenridding valley, lie the well known Greenside lead mines and works. They have been established and successfully worked for, I believe, 40 or 50 years; and the workings into the hill are very numerous and extensive. The lead ore is not merely separated and prepared (as at Thirlmere) but it is also smelted, and the produce sent away to Penrith in the shape of pig lead, the coal for the smelting

ing brought by the return carts. Some of the ore con-
ns silver, and this is also separated and smelted on the
emises.

80. The magnitude of the workings may be deduced
›m the information given me, that from 25 to 30 tons of
g lead are sent away weekly.

81. The crushing and washing processes for separating
e galena from its earthy matrix are the same as
scribed at Thirlmere, but on a much larger scale. There
e two different sets of works for the purpose, in different
rts of the valley, and the refuse is turned into the Glen-
lding beck and carried down into the south end of the
ke, forming large deposits, and discolouring the water for
great distance around.

I have brought away samples of the water.

Sample F c.—Glenridding beck.

82. This sample, two gallons, bottle No. 36, was taken
the 18th May from the Glenridding beck, about 100
rds below the crossing of the main road.

The stream was opaque white, like milk and water.

Sample F d.—Stream from Leadworks.

83. This sample, two gallons, bottle No. 42, was taken
e same day from the little stream running directly from
e leadwashing works, and, therefore, is much less diluted.
ıe actual working had stopped about an hour, or an
ur and a half, before I got to the place; but the water
›peared to be retaining its usual qualities.

Sample of the Deposit.

84. I also brought away a small sample of the earthy
›posit left by the water in the Glenridding beck, but this
›posit varied much in appearance at different places, and
doubt whether its nature may be correctly deduced from
ıe sample only.

85. There are other lead mines in adjacent valleys. It
›pears that levels have been opened in this district for
ad and other metals at various times for a long period,
ıd the traces of them are still seen in various places. It
ill only, however, be necessary to mention those that
›pear to be of importance at the present time.

86. I am told that a mile or two up the Grisedale valley,
›ening out close to Patterdale, there are mines which have
›en worked and given up again several times, the last
orkings having been very lately; and it is expected they
ıay again be resorted to. Nothing was doing when I was
ıere, and, therefore, I did not visit the site, but I have
rought away a sample of the water in the stream.

Sample F e.—Grisedale.

87. This is two gallons, bottle No. 35, taken 18th May,
little above Patterdale Hall. Water transparent and
olourless. Temperature 14½°.

88. In the Hayeswater valley, a little above the village of
ow Hartsop, there have been several workings at different
imes, old levels having been abandoned and new ones tried.

A pit is now being sunk at the junction of the Pasture
›eck, and worked with a horse gin. I am told that both
opper and lead ore are being found there, but there is no
vashing, nor any operation to pollute the water.

89. In the Upper Hartsop valley, however, about a quarter
f a mile above Hartsop Hall, there is a working of more im-
›ortance, as the mineral is crushed and washed by modern
nachinery on the spot, in the same manner as on Thirl-
nere, but on a less extensive scale. I am told that the
nines are ancient ones, resumed with success during the
ast few years. The ore is said to be rich in silver, but not
›lentiful, only about two tons per week being produced.

The machinery had been standing some days when I
visited the works, and therefore I did not take a sample
of the water; but the stream running from the washing
pits was still turbid and milky, and it was evident that
when at work it would send down much detritus.

90. The water from the mine runs by the Hartsop and
the Kirkstone becks into the south end of the little lake
called Brothers Water, where the sediment is deposited.

The stream running out of the north end of the lake is
quite clear and colourless; and after being joined by one
or two other rivulets, it becomes what is called Goldrill
beck, running through the village of Patterdale into the
south end of Ullswater. I have taken a sample from this
stream.

Sample F f.—Goldrill beck.

91. Two gallons, bottle No. 38, taken 18th May, ust
above Patterdale.

92. I am told that iron and copper ore are found in the
neighbourhood, but not at present in sufficient quantities
to pay for the working.

93. I have made inquiries whether any evil effects are at present produced on animal life by the water from these various works, but the facts are difficult to get at. It was said that in Ullswater, the char, and the fish called fresh water herrings, had disappeared or diminished, but that, both here and in Brothers Water, the trout were still plentiful and healthy, even near the mouths of the streams from the mines.

On the other hand, an intelligent farmer, the tenant of Hartsop Hall, told me he had frequently seen trout lying dead in the mine stream passing through his grounds, and that, in dry weather, when it was not much diluted, some of his live stock had suffered seriously from drinking it. It had been arranged he said, that it should be diverted, but this had not yet been done, as the workings were still experimental.

94. But apart from any noxious effects on health, it seems to me that the matter, whatever it be, at present brought down so plentifully from these works is likely to cause much trouble.

95. If the water is taken away from the south end of Ullswater, as soon as a current is established towards the discharge orifice, the matter held in suspension near the mouth of the Glenridding beck will inevitably find its way in that direction, and so the advantage of the lake as a settling reservoir will be lost.

96. But there is another evil which appears to me to deserve consideration on public grounds, independently of any water scheme. I mean the prospect of the more rapid silting up of the lakes where this detritus is deposited. We know that, geologically speaking, the lakes must, sooner or later, become filled up by the ordinary streams flowing into them, and the deposits round these are already very marked, particularly at the Patterdale end of Ullswater, where the flat meadows are evidently formed by deposited matter.

But under the natural course of things, this result would be protracted to a period that need cause no immediate alarm; whereas the artificial addition of detritus on such a large scale as is produced by these lead works will bring the effect to a much more proximate time. The mineral extracted from the mines, in order to get 25 to 30 tons of metallic lead, must amount to probably 600 or 700 tons weekly; and, though doubtless much of this is deposited on the hills, yet, if great care is not used, an enormous quantity will be sent down the stream, as the easiest way of getting rid of it. And this is shown in a practical way by what has already taken place, for the Glenridding stream has in these few years formed a delta at its mouth extending 100 to 150 yards out into the lake, and larger in extent than other similar streams have produced in a long course of time.

The effect in Brothers Water produced by the High Hartsop mines is still more striking. There a new cut has been made for the stream to enter the lake, and round the mouth of this stream, during the two or three years these comparatively insignificant mines have been at work, there has been formed a white delta tongue, 30 or 40 yards long, and 10 or 20 yards wide.

If these mines should go on, Brothers Water must in a great measure be destroyed; and in regard to Ullswater, which is of more importance, I believe that the south end of the lake must be very shallow, and that its silting up must progress rapidly.

97. Hitherto the three workings I have mentioned, namely, Glenridding, Thirlmere, and Harsrop, have been the only ones worked to any extent; but a general idea seems to exist of the possibility of other large veins being found; and, of course, if other important workings should be established in the district, or if the present ones should be materially extended, the difficulties arising from them would be magnified in a corresponding degree.

98. It has been proposed to divert the fouled drainage from the Glenridding works, to conduct it by conduits or pipes along the margin of the lake, and to deliver it into the river Eamont below the outlet. But under the present mode of working, I fear such conduits would be difficult to keep clear from stoppage by the deposit; and I should think the nuisance caused by delivering such a mass of detritus (which is at present arrested by the lakes) into the rivers and estuaries below would be strongly objected to.

99. I shall make some general remarks on the subject of lead workings in my report on the selection of samples in the Welsh district, where also they are carried on extensively; but I may say here that I am convinced it would be possible, by the extended use of subsiding tanks, and by great care in arresting and stacking the earthy matter on the hills, to reduce the water flowing away to such a state as would be either innocuous or capable of easy diversion; and I believe, therefore, that the existence of these leadworks need not necessarily form any bar to the use of the district for water supply.

G.

Addition to Ullswater Drainage.

100. It is proposed to add to the natural drainage of Ullswater, the gathering ground of about 13 square miles, drained by the *Dacre beck*, which falls into the Eamont about 1¾ miles below Pooley Bridge. It is proposed to tap this stream a little below the village of Dacre, and to convey its waters by a conduit to the north end of Ullswater.

101. The drainage ground of this beck is of a different character to that of the chief districts; it is over the old red sandstone and the carboniferous limestone; the lower part of the ground is comparatively low and flat, and is much cultivated. I should doubt whether the quality of this water will be equal to that from the other districts.

102. The *sample G.*, two gallons, bottle No. 45, was taken on the 20th May from a point immediately below Dacre bridge. The stream runs over limestone rocks covered with vegetation. The water was clear and colourless. Temperature 15°.

H.

Additional Drainage on the Southern Slopes of the Main Range of Hills.

103. In case the demand for water should become greater than can be supplied by the portions heretofore named, Messrs. Hemans and Hassard propose a measure for obtaining additional catchment area, to the extent of 53 square miles, from the southern slopes of the great east and west range of mountains before mentioned.

This area is coloured red on their map; and it will be seen that it is proposed to form a series of intercepting conduits, along the sides of the hills, from Rydal on the west to Borrow beck on the east, and so to catch a large portion of the waters which now find their way from these slopes into Windermere, the river Kent, or the river Lune.

104. This area being unprovided with any natural lakes at sufficient altitudes, it is proposed to form four artificial reservoirs, in the valleys of the Trout beck, the Kent, the Sprint, and Bannisdale beck, in which the waters would be stored, and from which they would be allowed to run off, either into the main conduit, for conveyance to a distance, or into their natural courses for compensation as might be desirable.

I have looked at the sites proposed in the two first-named valleys, and they seem favourable, regard being always had to the payment of compensation for injury done to lands or buildings.

105. The rocks on some portion of this district are different, geologically, from those on the northern side, but they are members of the same series, the Silurian and Cambrian, and will probably be equally innocuous as regards the water supply.

106. The nature of the surface is also generally very similar in the high portions of the district; lower down in the valleys of the Kent and its tributaries the streams pass over populous and cultivated land, and there are woollen and paper mills upon them, which defile the water, but these parts are below the lines of interception, and care would of course be taken not to admit any of this foul water into the conduits by which the main supply flows along.

107. Before leaving London, Dr. Frankland and myself thought it would suffice for this district to take a sample of eight gallons at the junction of the Sprint and Kent, a little above Kendal; but on visiting the spot for this purpose, I found the water so fouled by manufactories, by sheep-washing, &c., that it would give no idea of the upper drainage proposed to be taken. I therefore went higher up into the valleys and selected the following.

Sample H a.—Stockgill beck.

108. Two gallons, bottle No. 2, taken 23rd May above Ambleside, between the waterfall and the Bobbin mill.

Stream clear and colourless, vegetation on pebbles. Temperature 7°.

Sample H b.—Trout beck (Windermere).

109. The stream in this pretty valley comes down from near the summit of Kirkstone pass, and debouches into Windermere. The sample, two gallons, bottle No. 21, was taken 30 or 40 yards above the bridge at Trout beck village, and a little below the foot of the proposed reservoir.

Water transparent and white, with a little vegetation on the pebbles.

Sample H c.—Upper Kent.

110. Four gallons, bottles Nos. 9 and 32, taken 24th May at the Waterfoot bridge, just below the lower end of the proposed reservoir.

111. It was a powerful stream running 15,000,000 to 20,000,000 gallons per day, but as there is a reservoir in the upper part of the valley (made for the accommodation of the mills below), probably this was more than the normal flow.

The water was clear and colourless.

Leadworks in Kent Valley.

112. A little below the place where this sample was taken there is a lead mine, and some apparatus for washing the ore; but the whole thing is at present very insignificant, and it was not working when I was there. It is also below the point of interception, and the water from it, if fouled, could be prevented from interfering with the supply.

The only way in which it deserves consideration is, that this and other workings which, I am told, are being prosecuted in the neighbourhood afford evidence that lead exists about this part, and that the working for it might give trouble hereafter.

Sample H d.—River Sprint.

113. This sample, two gallons, bottle No. 7, was taken 24th May, at a point near the Sprint corn mill. This is much below the place where the stream would be intercepted, but the water looked clean.

I have, &c.

William Pole.

List of the Samples taken.

Those marked * are flood samples.
Those marked † contain water from mineral workings.

Distinguishing Letter.	Number of Gallons.	Number on Bottles.	Place.
A a	8	12 55 59 60	Thirlmere.
A b	2	40	Feeder to ditto.
A c†	2	47	Stream from lead works.
B a	2	51	Watendlath tarn.
B b	2	53	Naddle beck.
B c	2	49	Trout beck (Greta).
B c*	2	57	„ „ in flood.
B d*	2	58	Mosedale beck „
B e	2	46	Helvellyn gill.
B f	8	14 16 19 33	Upper Rothay.
C a	8	34 43 44 50	Haweswater.
C b	2	52	Measand beck.
D	2	37	Upper Lowther.
E	8	13 29 39 41	Lower Lowther.
F a	8	1 3 4 5	Ullswater.
F b	2	56	Airy beck.
F c†	2	36	Glenridding beck (lead).
F d†	2	42	Stream direct from lead works.
F e	2	35	Grisedale beck.
F f†	2	38	Goldrill beck.
G	2	45	Dacre beck.
H a	2	2	Stockgill beck.
H	2	21	Trout beck (Windermere).
H c	4	9 32	Upper Kent.
H d	2	7	River Sprint.

Journal of the Weather.

1867.		
May 10	Travelling to Keswick	Showers.
„ 11	Trout beck, &c.	Heavy showers in forenoon.
„ 12	(Sunday)	Fine and cold; easterly wind.
„ 13	Thirlmere, &c.	Fine and cold; a little snow on high hills in the morning.
„ 14	Watendlath, &c.	Fine and cold.
„ 15	Trout beck and to Penrith	Fine and cold.
„ 16	Haweswater, &c.	Very fine; sunshine; wind N.W.
„ 17	To Patterdale	Cloudy; cold; light rain.
„ 18	Lead mines, &c.	Fine; wind S.
„ 19	(Sunday)	Fine; calm.
„ 20	Upper Ullswater valley, &c.	Fine; cold; strong easterly wind.
„ 21	Pooley Bridge, &c.	Cold; stormy; showery; strong N.E. wind.
„ 22	Grasmere	Snow and hail; strong N.E. wind.
„ 23	Windermere	Cold; light showers.
„ 24	Kent, &c.	Fine; cold.
„ 25	Travelling back	Fine; cold.

APPENDIX B.

REPORT on the SELECTION of SAMPLES of WATER in the District of NORTH WALES.—By WILLIAM POLE, F.R.S., Mem. Inst. C.E. (*This Report is illustrated by the Map, Appendix E. 2.*)

SIR, Westminster, 19th June 1867.

1. I HAVE to report that in obedience to the instructions of the Commission I have visited the water-collecting districts of the Upper Severn, in North Wales, proposed by Mr. J. F. Bateman as sources of supply for London and other large towns.

2. I beg leave to refer to my former report of the 29th of May last for an explanation of the general manner in which I have carried out the instructions given me.

3. I was furnished with Mr. Bateman's published pamphlet on the subject, and a copy of his evidence before the Commission, and I received further explanations from him personally before my departure.

4. When I first arrived in the Northern district it had been raining heavily, and I was obliged to take the samples of the Vyrnwy and Banw in a state of flood. I then went to the Southern district, and as the weather had cleared up the streams there had had time to subside, and had apparently arrived at a fair weather condition.

It seemed to me very desirable that, if possible, all the streams should be taken under nearly similar circumstances, and as the weather still remained generally fine I paid a second visit to the Northern district, and obtained fine-weather samples there also. So that as regards these streams the Commission have samples taken in very different conditions, the comparison of which will doubtless be of considerable advantage.

I regret that this double work prevented me from going to Bala lake, samples from which were desired by Doctor Frankland.

5. Mr. Bateman's project comprises two separate water-collecting districts, each consisting of several drainage areas; and it will be convenient to classify the samples in accordance with these divisions, as follows:

Southern District.

M. Drainage area of the Severn Proper.
N. " " Tylwch.
O. " " Clywedog.
P. " " Tarannon and Ceryst.
Q. " " Carno.

Northern District.

R. Drainage area of the Banw and its tributaries.
S. " " Vyrnwy.

SOUTHERN DISTRICT.

6. The geological and mineralogical nature of the rocks in this district will be already well known to the Commission; I believe they are analogous to the rocks in the lake district of Cumberland and Westmorland, and they will, I have no doubt, be considered equally favourable for water collection.

7. The conformation of the land in the higher parts of the district is also of a favourable character, though it differs somewhat from that of the lake area. The hills, though generally steep and well marked, are of less altitude, and less abrupt and precipitous, their forms being more rounded; there is not much bare rock, but the surfaces are covered with grass, used for cattle and sheep pasture.

8. In descending the valleys cultivation begins, trees appear, and the population increases; and lower down, as the valleys widen out and the hills diminish, these features spread over a larger area. In some places attempts are made to extend the cultivation to a considerable altitude, but they do not seem very successful. In the lower and flatter parts of the district the land appears fertile and well tilled, but these form, I believe, only a small proportion of the whole drainage ground.

9. In the higher parts (as in the lake district) patches of peat moss frequently occur. I have seen in several places beds of peat of considerable extent being cut, and I find this forms almost the only fuel used by the residents on the higher ground. My samples in this district being all taken in fine weather, there was no brown colour in the water, but, by the analogy of the flood samples in the Vyrnwy and Banw, I presume the streams here also will be brown in flood time.

10. The lead workings and woollen factories have been mentioned as offering objections to the quality of the water in this district, and I have therefore thought it right to give particular attention to them.

11. I have marked on the accompanying map the places where the samples were taken, as also the position of the lead works and woollen factories mentioned in this Report.

LEAD WORKINGS.

12. I learned from Mr. Bateman's evidence that at the time he made his survey, some years ago, he found lead workings upon the Severn Proper, above Llanidloes, on which account he excluded that river from his scheme. On inquiring into this on the spot, however, I found that since that date the mining operations had undergone much change. It was said that the works on the Severn were no longer in operation, but that others had been established on nearly all the other streams comprised in this division of Mr. Bateman's plan. This subject therefore appeared of so much importance that I judged the Commission would desire me to ascertain the facts on the spot, and to report these facts to them. I first inquired at Llanidloes what lead works were in operation in or near the district, and then visited such of these as appeared most deserving attention, and I have given a summary of the information obtained at each place.

13. The lodes appear to vary considerably in composition. In the higher parts of the district, near Plinlimmon, they contain both lead and copper in a matrix of slate with quartz; in the lower parts the copper is not found, and the matrix consists almost entirely of slate. I am told, however, that in some parts calcareous and barytic spar occur as in Cumberland.

14. The general manner of preparing the mineral is the same as I have described for the Cumberland mines. No smelting is done in this part of the country.

Pant Mawr Mines.

15. These mines are not in the Severn district, but lie on the Upper Wye, about 3½ miles above the village of Llangurig. I thought it, however, right to go to see them, because they were mentioned in evidence before the Commission as having settling reservoirs, by which the injurious matter was said to be arrested, and the water sent down into the river clean and harmless.

I accordingly visited them on the 10th of June, but found that after being worked some years by the "Nanty Mining Company" they had been stopped some months since; the machinery had been sold and was being removed when I was there. The mineral had been extracted by steam power from the mine on the hill side, and had been passed down to a flat place on the bank of the river, where it had been crushed and washed in the usual manner.

I learned, by inquiries in the neighbourhood, that parties interested in the river had complained of the fouling of the water, and that litigation had taken place on the matter, in consequence of which the company had made settling tanks with the view of remedying the evil.

These consisted of a series of 15 rectangular ponds of various sizes, but occupying altogether about one-third of an acre, and each about four or five feet deep. The water passed through them successively and slowly, being decanted from the upper part of one tank into that next adjoining, so as to allow the sediment to deposit.

It was evident that these ponds had arrested much of the matter, as large heaps had been taken out of them. But I was informed by the clergyman of Llangurig (whose statements were confirmed by the landlord of the Bwlch Inn, a little higher up,) that the evil had not been perfectly remedied, for the water flowing down the river was still turbid, and the trout had still sustained injury. The clergyman, who, it appeared, was fond of fishing, had had his attention particularly directed to this subject, and had remarked that the effect of the poison on both trout and salmon was to give them a black colour, beginning at the tail. This effect had entirely ceased since the works had been stopped, and the fish had returned to the upper part of the river. I was informed that other lead workings had been opened higher up the valley, but that at present they were not of any important extent. The water in the river was perfectly clear and colourless.

Bryn-bos-du Mine.

16. This is said to be one of the most promising mines at present worked in the neighbourhood, and as I was led to believe it lay within the area of the Tylwch (or Dulas), one of the streams proposed to be appropriated, I went to see it on the 10th June.

I found it situated, not in a valley, as is most usual, but at a high level on a large bog forming the watershed between three streams, two tributaries to the Tylwch, and one running directly into the Severn. An old horse-gin pit has existed many years, but the present working is from another deep shaft drained and worked by steam power; and a new

one is being sunk, and a steam engine erected to work it. The mineral raised appears rich in ore, in a matrix of slate, without quartz or white spar.

The lead ore appears easily separated, and the separation and washing are done entirely by hand with very simple apparatus. Only a small quantity of water is used, the supply being raised from the shaft; after the washing it runs away very foul and of a dark slaty colour. It is allowed to flow into the bog, where its dirt appears to be absorbed, as I could not find traces of it in any of the streams.

The principal significance of this mine is as evidence of the existence of lead veins in this part of the district, and of the possibility of their being hit upon hereafter in places where their working would be of more importance to the drainage.

Llechwydd ddu, or Delife Lead Works.

17. These are the most important works in this part of the country. Mr. Hassard (Q. 1038) stated they were on the Clywedog, one of Mr. Bateman's streams, and the Ordnance map would appear to justify this assertion, but on visiting the works I found this was an error. At the place called on the map "Cwm Delife," although marked "Lead works," there is only a mine or shaft, and no "works" that I could see or hear of. The lead works lie on the north side of the hill called Llechwydd ddu, forming the water dividing ridge between the Severn and the Dyfi, and the drainage from them flows down the Twymyn to Llanbrynmair, and so by the Dyfi into the sea, a little north of Aberystwith.

The works are large, belonging to an association, one of whose principal members is Mr. John Bright, M.P. They are well laid out with all the most modern apparatus and machinery, and apparently very well managed. The work people were the best in appearance I ever saw in a mining district. About 200 hands are employed, and the produce, I was told, is about 25 or 30 tons per week, equivalent to about 20 or 25 tons of metallic lead, or something less than the Glendinning mine at Ullswater. The ore is not smelted on the premises, but is sent away for sale. A good deal of copper ore is also obtained along with the lead; this is put aside, and crushed and washed at intervals when there is sufficient quantity.

The manager, Captain Evans, took me over the works, and explained that complaints having been made of the fouling of the river below, the proprietors had laid out subsiding ponds at some distance down the valley, which I went to see. They are on the same principle as I have described at Pant Mawr, the fouled water being allowed to remain some time in each, and to decant from one to the other. It was evident that they did much good, by the quantity of deposit settling in them; and it is, I think, certain that any particles of lead ore which may come away must be deposited here. But some of the slaty and earthy matter appears to be so light, and to be levigated so finely, as still to remain in suspension, for I found the water flowing away from the last pond still turbid enough to render the bottom invisible at two or three inches depth.

Such a stream as this flowing into the rivers below, would, however, do very little mischief mechanically by deposit; and as to its effect on animal life, I noticed a fact which was strong evidence of its innocuousness, viz., that cattle were kept by a neighbouring farmer in the fields through which this stream ran, and sustained, apparently, no injury therefrom. I saw about 20 healthy looking young bullocks in one of the fields, some of whom were drinking from the stream just at its issue from the last settling pond.

There is still said to be some injurious effect on the fish, as complaints continue to be made, and this corroborates the testimony of the clergyman of Llangurig mentioned in paragraph 15.

Dwngwm Lead Works.

18. This mine immediately adjoins those of the Llechwydd ddu last described, but the shafts and works lie on the south side of the hill, and drain into the head of the valley of the Clywedog, one of Mr. Bateman's streams. The mines produce lead and copper ore, which is crushed and washed on the premises by machinery of the usual kind, but the works are much less extensive than those adjoining. There are no settling ponds, beyond the small usual "slime pits" used for completing the separation of the ore; but the fouled water from these, and the other parts of the machinery, runs directly into the stream.

I was told that the works had not been lately prosecuted with vigour, they sometimes employed about 60 hands. On the day I was there, the 11th June, only a few were at work, and no lead was being prepared; they were crushing and washing a stock of copper ore which had accumulated, and which it was desired to get rid of. The refuse water was but small in quantity, but it was very foul.

I took a sample of the water of the stream at "Stay little," about two miles below, but this only represents a exceptional state of things, and it must be borne in min that it is at any time possible that the mine might b worked vigorously, and might even rival the neighbourin one in extent and importance.

The Fan Mine.

19. This is an extensive working on the left bank of th Ceryst, about half a mile above the crossing of the road t Llanbrynmair, and just at the head of Mr. Bateman's gre reservoir. I visited it on the 13th June. It is a recent discovered lode, and is said to be successful; the machine is worked by a waterwheel of 50 or 60 feet in diameter, on the most modern and complete plan, and capable, I w told, of preparing nearly 20 tons of lead ore per wee though it did not appear to me that anything like such quantity was at present produced.

The refuse water from the separating pits runs into series of five settling ponds, each about 25 feet by 12, whe some of its matter is deposited. These have been put u lately, probably on account of complaints from the riv below, but they are much too small to be effective, and th flow into the river from them is very dirty. I have broug a sample of the river water contaminated with this refus taken about half a mile below the mine.

20. The above mentioned are the only works I thoug it necessary to visit, but there are several others whi have been worked lately and which may be resumed. T two mentioned by Mr. Bateman on the Severn must be, should think, the *Nant Melyn* or "Severn" mines, ne the source, and those of *Cwm rhicet* a little lower dow Both these are now stopped, and the machinery of t former is sold. Other mines, I believe, exist on or ne Plinlimmon, but I do not know their exact locality. The is a mine of some importance on the left bank of t Clywedog called *Bryndael*, but it is not now at work; a there is also another in the valley of the Ceryst, the nam of which I forget.

The mining speculations appear so uncertain and chang able that it is impossible either to reckon on the permanen of any mines that are working, or to foresee where wor may be prosecuted in time to come. The Ordnance Ge logical Survey shows that metallic lodes traverse the distri in various directions, and wherever these are found w must look for a possibility of operations being sooner later carried on.

21. It appears to me that the following inferences m fairly be drawn from the information obtained on the su ject of these mining works:—

1. It would appear useless to attempt to exclude th streams on which they occur. They already exist o several, and may exist on all.
2. From the places in which they lie, generally so high t the valleys, I should think it would be scarcely po sible to divert their drainage, particularly as the are few works sufficiently permanent to warrant a large expense being incurred with this object.
3. The fouling of the water may be either mechanical chemical. The former is, I think, amenable to ea treatment. Great pains are taken to extract from th mineral all the metallic ore it contains; and I shou think, therefore, very little of this can pass off. believe the matter carried down consists almost e tirely of the lighter earthy substances, separated fro the ore and held in mechanical suspension by th washing water passing away.

   Where there is no inducement to be careful, a gre quantity of this matter is thrown or allowed to pa into the stream, such being the easiest way to get r of it. But the practice of mines better managed lea to the belief that if the plan of subsiding ponds we sufficiently carried out, and all possible care take to stack the débris on spoil banks, the matter passin away might be reduced to a very small amount, an to a very light kind, which would probably subsi in large reservoirs without doing any harm; or necessary even this might be arrested and the wat rendered perfectly limpid by some simple mode filtration, which I was told by one of the minin managers had already been partially tried.
4. The question of chemical contamination by matt dissolved in the water I am unable to offer any opinio upon. The chemists will doubtless report on the fe samples I have brought from this and the lake di tricts; but the composition of the various metalli lodes appears to be very diversified, and probably n result derived from the analysis of one or two woul be of general application. I have been told of th suspected existence, in some cases, of arsenical salt and in others of some free acid, deleterious to fis

but very little definite information is to be obtained in the districts themselves. The question has been agitated in several places, by parties interested in the river fisheries, and probably the Commission might obtain useful evidence from some of their officers. I should imagine that if any noxious matters should be found dissolved, it might not be beyond the power of chemical and metallurgical science to find a remedy, if its application would be worth the trouble; but it must be borne in mind that the quantity of impurity must, in most cases, be extremely small when compared with the large dilution by the flood waters of the streams.

Woollen Manufactories.

22. This part of the country is noted for its manufacture of Welsh flannel, and the mills have been mentioned as defiling the water, but the more important of them are close to Llanidloes, below the intercepting conduits of Mr. Bateman's water collection.

I visited some of these works, where I find the wool is carded, spun, and woven into flannel in the usual way. The only part of the process likely to injure the water is the cleaning or "fulling" of the flannel when it is made. To extract the grease and dirt it is treated with fuller's earth and beaten by heavy wooden mallets worked by machinery, being well washed with water during the process; the water running away must, of course, be injured, although it did not look dirty. In some of the mills I noticed that the wool was washed before carding, but this does not seem to be general.

23. I could only ascertain the existence of four works within Mr. Bateman's drainage area, and all these I saw. The two most important are on the left bank of the Clywedog: the upper one, Glyn mills, belonging to Mr. Clayton, and situated about a mile and a half above the junction with the Severn, are large works employing about 100 hands, the other one is smaller and a little lower down.

The "factory" on the Severn, marked on the Ordnance map, has ceased to work; at Cae-yn-y-coed, a little lower down, I found one with a fulling mill adjoining, but the whole thing is very small.

And there is a still smaller carding mill on the Tylwch, on the road to Llangurig, about two miles from Llanidloes, but there is nothing done here to dirty the water.

24. I do not attach much importance to these mills, as I believe it would be easy to divert the drainage from them so as to prevent it from fouling the streams.

25. I now proceed to explain where the various samples from this district were taken.

M. Severn Proper.

26. I have already stated that this was excluded by Mr. Bateman, on account of lead works upon it when he made his survey; but as these works are not now in operation, I have thought it right to take a sample.

It is a fine stream, draining an area of about 20 square miles of the highest and most favourable land in the district, and it was running, when I saw it, a large quantity for the area, namely, above 20,000,000 of gallons per day. There is a small woollen factory, mentioned in paragraph 23.

Sample M,

Eight gallons, bottles Nos. 64, 81, 92, and 93, was taken, 13th June, just above the factory. The water was beautifully clear and colourless.

N. Tylwch.

27. This stream drains about 25 square miles and runs into the south side of the Severn, a little above Llanidloes. The area seems flatter and more cultivated than that of the rivers rising more to the westward.

Two railways have lately been made in this valley, the "Mid-Wales," which runs from Llanidloes by Tylwch and Pant-y-dwr to Rhyader and South Wales; and a line called the "Manchester and Milford," which, branching off from the last one, ascends the tributary stream to the westward, and dips into the valley of the Wye at Llangurig, where it stops. It has never been worked.

There is a lead working on the edge of the drainage, and a small woollen factory in the district, but neither of them do any harm to the water.

Sample N,

Four gallons, bottles Nos. 70 and 71, was taken, 12th June at the crossing of the road to Llangurig. The stream was clear and colourless, running 8,000,000 to 10,000,000 gallons daily.

O. Clywedog.

28. This stream, like most of the others in this division, drains about 25 square miles. It is proposed to form a small reservoir upon the upper part of it near the village of "Stay a little," where a favourable site exists for the purpose.

On this river there are two mining works, at Dwngwm, near the head of the stream, and at Bryndael; the latter was not at work when I was there, and the former was working, exceptionally, copper ore. (See paragraph 18.)

Sample O a,

Two gallons, bottle No. 6, was taken just above "Stay a little," and about two miles below the Dwngwm works. The stream was running 2,000,000 to 3,000,000 gallons daily. Water slightly turbid.

There are also two woollen factories on the stream. (See paragraph 23.)

Sample O b,

Eight gallons, bottles 74, 75, 77, and 86, was taken, 13th June, just above the upper factory. The water was transparent and colourless, and was running, like the Severn, above 20,000,000 of gallons daily.

P. Tarannon and Ceryst.

29. These two rivers, in the lower part of their course, traverse a flat, expanded valley below Trefeglwys, and join together shortly before entering the Severn. The drainage area is about 25 square miles.

The valley narrows at its lower end, and Mr. Bateman proposes to throw a dam across at this point, which will convert the whole of the Trefeglwys valley into an immense lake for storage. Into this lake the water from the whole of the other rivers will be conducted, and from it the conduit will issue to convey the supply away.

The Tarannon is the more important stream. It is unaffected by any accidental causes of impurity.

Sample P a,

Six gallons, bottles Nos. 24, 69, 80, was taken on the 12th June, from the bridge on the main road near Trefeglwys. Water clear and colourless, running about 6,000,000 gallons per day.

The Ceryst is much smaller, and is much fouled by the refuse from the "Fan" mine. (See paragraph 19.) There are also other mines upon it which were not working when I was there.

Sample P b,

Two gallons, bottle 94, was taken on the 13th June, at the crossing of the road, about half a mile below the Fan works. Water turbid and dirty, running about 3,000,000 gallons per day.

Sample P c,

Eight gallons, bottles Nos. 65, 66, 67, 78, was taken, 12th June, a little below the junction of the two rivers. The water was dirty, bottom not visible at more than about 12 inches deep. This may have been caused partly by the mine, but also partly by running over the clay bottom of the flat valley.

Q. Carno.

30. This stream drains about 25 square miles. The railway to Aberystwith runs up the valley. I have not heard of any mines or factories upon it.

Sample Q,

Eight gallons, bottles Nos. 61, 62, 63, 68, was taken, 12th June, from the point where it is proposed to tap the stream, about half a mile above the little village of Pont-y-ddolgoch. Water clear, but a slimy deposit on the pebbles. Quantity small for the area, only about 3,000,000 or 4,000,000 gallons per day.

NORTHERN DISTRICT.

31. The general remarks in paragraphs 6 to 9 will apply to this district also, which is of a very similar character. I think, however, that in some parts, as for example, near Can Office, on the Banw, there is more cultivation; and in others, as near Lwydiarth Park on the Vyrnwy, there are more trees.

On the other hand this district, as far as I know, is entirely free from manufactories or mineral workings.

32. I have had the good fortune to obtain two sets of samples from this district, the first in flood, the second about a week afterwards in fair weather.

R. Banw and its Tributaries.

33. This part of the district is composed of the drainage ground of the river Banw, and its tributaries above Rhyd-y-gro, comprising about 50 square miles.

Three reservoirs are to be formed in this area, two upon the river itself, and one on the tributary stream called the Eira, falling into it a little below Can Office.

Dr. Frankland had suggested that an 8-gallon sample of water taken below the junction of the large tributary, the Eira, would suffice for this district. But as there was a little difference in appearance between the flood water of the Banw Proper and that of the tributary, I slightly varied the proposal by taking four gallons of each of the streams, and four gallons of the combined river beyond the junction. These can either be mixed together or examined separately, as the chemist may prefer.

Sample R a.—Banw above Eira.*

34. This sample, four gallons, bottles Nos. 28 and 30, was taken on the afternoon of 6th June, a little above the inn at Can Office. The weather had been wet for some days; it had rained heavily in the morning, and the river was full and rapid. It was running 12 inches deep (with an approaching velocity of two or three feet per second) over a weir 60 feet wide, and with a mill race in addition, giving about 130,000,000 gallons per day, equal to about one-third of an inch per day over its whole drainage area.

The water was brown and rather turbid, but the bottom could still be seen through a depth of 9 to 12 inches of water.

Sample R b.—Eira.*

This sample, four gallons, bottles 8 and 37, was taken the same day as the last, at a point about a quarter of a mile above the junction.

The valley of this stream appeared (as far as I could judge without going up it) flatter and lower than that of the Banw, and the water was somewhat different in appearance. The brown colour was rather less deep, but the water was more muddy and turbid; the bottom being hidden at about six inches deep.

The quantity appeared almost as great as in the Banw, but I had no means of gauging it easily.

Sample R. c.—Banw and Eira combined.*

36. This sample, four gallons, bottles Nos. 26 and 31, was taken the same day, just above the bridge of Llanerfyl. Water brown and turbid, bottom not visible at greater depth than six inches.

37. I went up the main valley, as far as the water dividing ridge, but did not perceive any necessity for taking additional samples. All the streams had the same brown colour up to their sources, or at least to the highest points to which I could trace them, and I believe most of them rise in the peat mosses from which this colour is derived.

But in the upper parts of the valley these streams though brown were always transparent. It was only in lower ground that the small rivulets, draining from the rainfall over the alluvium of the flatter lands, introduced the turbidity and slight dirtiness remarked where the samples were taken.

38. I had the opportunity of watching these streams for some little time after I took the samples, when the weather was clearing up, and found them change very rapidly.

The Banw, for example, at Can Office, which on the 6th at 2½ p.m. was running 130,000,000 gallons per day, had at 3½ p.m. on the 7th diminished to about 90,000,000. It had, moreover, lost its turbidity and become transparent, but had retained its brown colour. At 8½ p.m. the same day it was reduced to something above 50,000,000, and at 8 a.m. on the 8th to under 30,000,000.

Similar changes had taken place in the Eira and at Llanerfil bridge; the brown colour remaining fully preserved in all cases.

The rapid change in appearance led me to think that, though probably the peaty brown colour may be a constant characteristic of the streams in rainy weather, the turbidity is only a transient superficial effect following immediately from actual rain, and disappearing very soon. If this is so, when the water is stored in large reservoirs the sediment would probably soon subside and cause no trouble.

Second Sample R c.—Banw and Eira.

39. Eight gallons, bottles Nos. 72, 73, 76, 79. This second sample was taken at Llanerfyl bridge on the 14th June, eight days after the former one, during which time there had been no rain to speak of. The Banw above Can Office had dwindled to less than 10,000,000 gallons, and the Eira to less than 5,000,000. The water was quite transparent and colourless in both streams.

S. Upper Vyrnwy.

40. Mr. Bateman proposes to make use of a large gathering ground of about the same area as the last at the head of the river Vyrnwy, extending down to Pont Hagel, a large reservoir being formed on the main stream, as shown in Mr. Bateman's pamphlet.

At Pont Hagel the water is to be diverted from its natural course and turned by a tunnel into the lowest reservoir of the last-mentioned district above Rhyd-y-gro.

It appeared sufficient for this district to select one place for the example, namely, the point at which it is intended to carry the water away.

Sample S.—Vyrnwy.*

This sample, eight gallons, bottles Nos. 15, 17, 22, 25, was taken at Pont Hagel on the 7th June. The weather had been rainy, but had cleared up that day.

It was a fine, large, and rapid river, running probably above 200,000,000 gallons per day. The water was brown but transparent.

Second Sample S.—Vyrnwy.

This second sample, eight gallons, bottles Nos. 82, 83, 95, 96, was taken on the 14th June, from the same place. The stream had diminished to about one-tenth of what it was before, and the water had become perfectly colourless.

I have, &c.

William Pole.

Arthur Lennox, Esq., Secretary,
Royal Commission on Water Supply.

List of the Samples taken.

Distinguishing Letter.	No. of Gallons.	Number on Bottles.	Place.
			Southern District.
M	8	64 81 92 93	Severn.
N	4	70 71	Tylwch.
O a†	2	6	Clywedog, Upper.
O b†	8	74 75 77 86	„ Lower.
P a	6	24 69 80	Tarannon.
P b†	2	94	Ceryst.
P c†	8	65 66 67 78	Tarannon and Ceryst.
Q	8	61 62 63 68	Carno.
			Northern District.
R a	4	28 30	Banw.
R b*	4	8 27	Eira.
R c*	4	26 31	Banw and Eira.
R c	8	72 73 76 79	Do.
S*	8	15 17 22 25	Vyrnwy.
S	8	82 83 95 96	Do.

Those marked thus * are flood samples.
Those marked † contain water from mineral workings.

Journal of the Weather.

June 4th	Travelling - -	Showers (heavy rain on previous day).
„ 5th	Shrewsbury and Can Office, getting up bottles, &c.	Rain, with fine intervals.
„ 6th	Banw, &c. - -	Much rain in morning, finer in afternoon.
„ 7th	Vyrnwy - -	Rain in morning, fine in afternoon.
„ 8th	To Llanidloes -	Fine.
„ 9th	(Sunday) - -	Very fine.
„ 10th	Lead Works - -	Do.
„ 11th	Do. - -	Do.
„ 12th	Tarannon, Carno, Tylwch.	Fine, but light showers in previous night.
„ 13th	Severn, Fan Mine, Ceryst, Clywedog.	Do.
„ 14th	Banw and Vyrnwy -	Light showers.
„ 15th	Packing and sending off bottles.	Rainy.
„ 16th	(Sunday) - -	Do.
„ 17th	Home.	

APPENDIX C.

SUPPLEMENT to REPORT on the SELECTION of SAMPLES of WATER in the WELSH DISTRICT.—By WILLIAM POLE, F.R.S., Mem. Inst. C.E.

SIR, Westminster, 13th July 1867.

1. IN paragraph 4 of my Report on Mr. Bateman's district I stated that from the necessity of going twice to the Vyrnwy and Banw, I was unable at that time to get samples from Bala Lake, which were included in my instructions.

2. The drainage ground of this lake does not form part of Mr. Bateman's scheme, but it was considered desirable, both by him and by Dr. Frankland, that samples of its waters should be collected along with the others, in order to ascertain the effect which storage in a large reservoir would have on waters considered analogous to those of the Severn district, and supplied from the same hills.*

3. I therefore visited the lake on the 2nd of July. The weather had remained fair from the time the other Welsh samples were taken, till the 1st of July, on the evening of which day, as well as on the 2nd there was some rain, but not enough to have much apparent effect on either the quantity or quality of the streams. The lake was very low, and the quantity flowing both in and out very small for the drainage area.

4. The district appears to be generally of the same nature as those selected by Mr. Bateman, except that the hills around it are higher. I should think the water flowing from it would be of very nearly the same character. On the higher grounds peat is said to exist, which is cut and burnt for fuel, and the streams are said to be brown in rainy weather.

5. I took samples from the lake itself, and from four of its principal feeders.

6. The water from the lake, which I may distinguish as—

Sample Bala (a.)

(Eight gallons, bottles Nos. 20, 86, 87, 88,) was taken in a boat, about a quarter of a mile off the village of Llan-y-cil.

Sample Bala (b.)

(Four gallons, bottles Nos. 23, 91,) was from the Twrch near the road-crossing at Pandy. This is the principal feeder which comes from the south, and whose drainage area is contiguous to that of the Vyrnwy. There is a small woollen mill and a tanyard on the lower part of this stream.

Sample Bala (c.)

(Two gallons, bottle No. 89,) is from the Dwfrdwy, near the bridge at Llanwchllyn. Stream slightly tinged brown, with white scum.

Sample Bala (d.)

(Two gallons, bottle No. 10,) is from the Afon Llyn at Pont Lliw. There is a gold mine on this stream at Castell Carndochan, and I am told that at certain times, when the quartz is crushed, the stream is rendered milky. There was nothing doing when I was there, and the water was clear.

Sample Bala (e.)

(Two gallons, bottle No. 18,) is from the Afon Llafar, at the road-crossing. Water slightly turbid, with white scum.

7. I should mention that a railway (from Bala to Dolgelly) is now being constructed on the south bank of the lake, the rails will, I believe, be only about 2 feet above the highest flood level (or 6 or 7 feet above drought level) and therefore this will be an obstacle to any raising of the lake with the view of increasing its capacity as a reservoir.

I am, &c.,
WILLIAM POLE.

Arthur Lennox, Esq., Secretary,
Royal Commission on Water Supply.

* The Bala Lake was proposed as a source of supply to Liverpool so long ago as 1846, by Mr. Rawlinson, C.B., and the proposal has been lately renewed, in a modified form, by Mr. Duncan, the engineer of the Liverpool Corporation Waterworks.

APPENDIX D.

REPORT on the CHEMICAL QUALITY of SAMPLES of WATER collected in NORTH WALES and in the LAKE DISTRICT of CUMBERLAND and WESTMORELAND.—By Dr. E. FRANKLAND, F.R.S., and Dr. ODLING, F.R.S.

To the Royal Commission on Water Supply.

MY LORD DUKE AND GENTLEMEN,

IN compliance with your instructions we have made an analytical examination of numerous samples of water from North Wales and from the lake districts of Cumberland and Westmoreland collected for the purpose by Mr. William Pole, F.R.S., whose report on the topographical and geological character of the respective gathering grounds has been already presented to the Commission.

The samples appear to have been most judiciously and carefully collected. Their large number, and the variety of meteorological conditions under which they were taken, have enabled us to make a very complete investigation into the quality of the water likely to be obtained from each of the districts.

The following table contains a list of the samples transmitted to us by Mr. Pole, the dates of their collection, the estimated flow of the streams at the time of collection, and our own remarks on the appearance of the samples when they arrived, and of the residues which they left on evaporation.

WELSH SAMPLES.

Place of Collection.	Date of Collection.	Estimated daily run of Water when Sample was taken.	Appearance of Samples, Remarks, &c.
Southern District.	1867.	Gallons.	
River Severn - -	June 13	20,000,000	Clear and colourless.
Tylwch - - -	„ 12	9,000,000	Clear and colourless. Residue left on evaporation slightly brown.
Upper Clywedog -	„ 13	2,500,000	Colourless and slightly milky. Residue left on evaporation slightly brown. Contains water from mineral workings.
Lower Clywedog -	1867. June 13	20,000,000	Clear and colourless. Contains water from minera workings.
Tarannon - -	„ 12	6,000,000	Clear and colourless, leaving a slightly brown residue on evaporation.
Ceryst - - -	„ 13	3,000,000	Milky, from fine suspended matter. Contains water from the washing apparatus of the Fan mine.
Tarannon and Ceryst, just below junction.	„ 12	3,000,000	Full of fine suspended matter.
Carno - - -	„ 12	3,500,000	Clear and colourless.
Northern District.			
Banw in flood -	„ 6	130,000,000	Clear but very yellow.
Eira in flood - -	„ 6	130,000,000	Clear and brownish yellow.
Banw and Eira in flood, after junction.	„ 6		Slightly turbid, and of a deep yellow colour, leaving a very brown residue on evaporation.
Banw and Eira after subsidence of flood.	„ 14	15,000,000	Clear and colourless, leaving a very slightly brown residue on evaporation.
Vyrnwy - -	„ 14	20,000,000	Clear and colourless, leaving a very slightly brown residue on evaporation.
Vyrnwy in flood -	„ 7	200,000,000	Clear and of a deep yellow colour.
Bala Lake and Feeders.			
Bala Lake - -	July 3		Clear, very slightly yellow.
Mixed samples from four feeders to Bala Lake.	„ 3		All the samples were clear, three were colourless, while the fourth had a slightly yellow tinge.

CUMBERLAND AND WESTMORELAND SAMPLES.

Place of Collection.	Date of Collection.	Estimated daily run of Water when Sample was taken.	Appearance of Samples, Remarks, &c.
Thirlmere District.	1867.	Gallons.	
Thirlmere Lake -	May 13		Clear and colourless, leaving a slightly brown residue on evaporation.
Main feeder to Thirlmere.	„ 13		Clear and of a slightly brown tinge.
Stream from Lead-works running into Thirlmere.	„ 13		Milky but colourless, leaving a white residue on evaporation.
Proposed additions to Thirlmere District.			
Watendlath Tarn -	„ 14		Clear, brownish tinge.
Naddle Beck - -	„ 13		Clear and colourless, leaving a brownish residue on evaporation.
Troutbeck (Greta)	„ 15		Clear and of a bright yellow colour, leaving a brownish residue on evaporation.
Troutbeck (Greta) in flood.	„ 11		Clear yellowish brown, leaving a nearly black residue on evaporation.
Mosedale Beck in flood.	„ 11		Clear yellowish brown, leaving a nearly black residue on evaporation.
Helvellyn Gill -	„ 13		Clear and colourless.
Upper Rothay -	„ 22		Clear and colourless, leaving a somewhat brown residue on evaporation.
Haweswater District.			
Haweswater Lake -	„ 16		Clear and colourless, leaving a slightly brown residue on evaporation.
Measand Beck -	„ 16		Clear and colourless, leaving a very slightly brown residue on evaporation.
Proposed additions to Haweswater District.			
Upper Lowther -	„ 16		Clear and colourless, leaving a brown residue on evaporation.
Lower Lowther -	„ 15	50,000,000	Clear and colourless, leaving a slightly brown residue on evaporation.
Ullswater District.			
Ullswater Lake -	„ 21	40,000,000	Clear and colourless, leaving a slightly brown residue on evaporation.
Airy Beck - -	„ 17		Clear and colourless.
Glenridding Beck -	„ 18		Milky even after filtration, leaving a white residue on evaporation.
Stream running into Glenridding Beck from Lead-works.	„ 18		
Grisedale Beck -	„ 18		Clear, slightly yellow.
Goldrill Beck -	„ 18		Clear and colourless. Contains water from mineral workings.
Proposed additions to the Ullswater District.			
Dacre Beck - -	„ 20		Clear, with a slightly brown tinge.
Stockgill Beck -	„ 23		Clear and colourless.
Troutbeck (Windermere).	„ 23		Clear and colourless, leaving a white residue on evaporation.
Upper Kent - -	„ 24	20,000,000	Clear and colourless, leaving a white residue on evaporation.
River Sprint - -	„ 24		Clear and colourless, leaving a very slightly brown residue on evaporation.

After the arrival of the samples of water they were allowed to stand for at least two days, to deposit suspended matter. About a quart of each water was then poured carefully into a flask, and the observations upon the colour and transparency, contained in the above table, were made. The appearance of each sample of water, as given above, may therefore be regarded as that which it would present if viewed in a quart decanter of flint glass.

We considered that, by thus allowing time for the deposition of suspended matters, the appearance of many of the waters would more nearly approach to that which they would present after storage in a lake or reservoir. It will be remarked that many of the samples mentioned by Mr. Pole as turbid at the time of collection are described by us as clear. In some cases also there is a discrepancy in our statements as regards colour. This is doubtless owing partly to the different conditions, as regards depth of water, &c., under which the observations were made, and partly, perhaps, to an alteration of tint during transit.

Chemical Examination of the Waters.

Each sample of water submitted to analysis was poured from the stoppered glass bottle in which it had been collected in such a manner as not to disturb any sediment. The total solid residue was determined by evaporating one litre (1,000 grams) (or in some cases half a litre) of the water to dryness in a platinum capsule placed upon a steam bath. The residue after being dried at 100° C. until it ceased to lose weight was then weighed in the usual manner.

There is no process known by which the accurate determination of the organic matter contained in potable waters can be effected, but, by a method recently devised by one of us, we have determined the amount of carbon and of nitrogen entering into the composition of the organic matter contained in the several samples submitted to us. For this purpose a litre of each water was acidified with sulphurous acid and evaporated to dryness. The dry residue was then burnt in vacuo with chromate of lead and oxide of copper, and the carbonic acid and nitrogen determined as gases. The nitrogen existing as nitrates and nitrites was estimated by evaporating nearly to dryness one litre of each water, transforming the chlorides into sulphates by the addition of sulphate of silver, mixing the resulting concentrated liquid with an equal volume of sulphuric acid in an inverted glass tube filled with mercury, and then agitating the mixed liquid with the mercury for a few minutes. The whole of the nitrogen present in the water as nitrites and nitrates was thus transformed into nitric oxide gas, the volume of which was then determined. The ammonia was estimated by Nessler's test, and the hardness by Clark's soap test.

These analytical operations were performed upon all the waters; but certain samples, such as those taken from the lakes and more considerable rivers, and of which larger quantities (eight gallons) were collected, were submitted to the more searching examination of a complete analysis. The mineral constituents in these samples were quantitatively estimated by the usual processes of inorganic analysis; whilst the gases held in solution were determined by boiling the waters for one hour in vacuo and collecting the expelled gases over mercury. The carbonic acid was determined by absorption with caustic potash, the oxygen and nitrogen by explosion with excess of hydrogen.

In the determination of the gases we were much indebted to the assistance of Mr. M'Leod, who performed the manipulatory operations with great skill and accuracy; every number in the annexed tables is the mean of at least two distinct and well accordant determinations.

The following tables exhibit the results of these analyses.

They are to be read thus:—100,000 lbs. of the water of the river Severn, collected on June 13th, left on evaporation a solid residue, which when dried at 100° C. weighed 3·369 lbs. The above quantity of water contained in solution solid mineral ingredients, from which the following substances were extracted by analysis ·417 lb. of lime, ·244 lb. of magnesia, ·147 lb. of potash, ·816 lb. of soda, 1·066 lb. of sulphuric acid, ·147 lb. of carbonic acid, ·200 lb. of silica, ·823 lb. of chlorine, ·007 lb. of nitrogen (which existed in the water as nitrates and nitrites), ·003 lb. of ammonia. The organic matters present in the same weight of water contained ·005 lb. of nitrogen and ·2 lb. of carbon. This amount of water yielded ·009 lb. of ammonia on ebullition with permanganate of potash. It also contained ·009 lb. of carbonate of lime or its equivalent of other soap destroying constituents, none of which was removed by boiling the water for half an hour. Finally 100 volumes of the water of the Severn contained 2·2 volumes of dissolved gases consisting of 1·412 vol. of nitrogen, ·641 vol. of oxygen, and ·147 vol. of carbonic acid.

We have, &c.,

E. FRANKLAND, F.R.S.
W. ODLING, M.B., F.R.S.

Royal College of Chemistry,
20th November 1867.

Results of Complete Analysis of Welsh Waters.

Names of Substances found.	Sources of Waters.								
	Severn.	Lower Clywedog.	Tarannon.	Tarannon and Ceryst.	Carno.	Banw and Eira.	Vyrnwy in flood.	Vyrnwy.	Bala Lake.
Total solid residue from 100,000 parts of water evaporated and dried at 100° C.	3·369	3·844	4·424	6·429	6·489	4·857	4·083	3·726	2·786
Mineral Substances in 100,000 parts of each water:									
Lime	0·417	0·519	0·510	0·814	1·126	0·746	0·567	0·479	0·217
Magnesia	0·244	0·299	0·351	0·381	0·374	0·404	0·159	0·237	0·144
Potash	0·147	0·053	0·243	0·141	0·117	0·131	0·089	0·099	0·114
Soda	0·816	0·664	0·570	0·830	0·916	0·690	0·490	0·609	0·527
Sulphuric acid	1·066	1·356	1·277	1·746	1·344	1·167	0·754	0·837	0·290
Carbonic acid	0·147	0·014	0·057	0·000	0·614	0·494	0·237	0·189	0·144
Silica	0·200	0·219	0·271	0·581	0·231	0·260	0·190	0·296	0·026
Chlorine	0·823	0·756	0·876	1·487	1·039	0·860	0·573	0·744	0·729
Nitrogen as nitrates and nitrites	0·007	0·006	0·024	0·068	0·049	0·023	0·000	0·011	0·000
Ammonia	0·003	0·004	0·008	0·000	0·003	0·004	0·003	0·003	0·001
Organic substances in 100,000 parts of each water:									
Organic nitrogen	·005	·001	·002	·001	·007	·004	·009	·005	·001
„ carbon	·200	·242	·282	·304	·335	·265	·963	·218	·227
Gases in 100 vols. of each water:									
Nitrogen	1·412	1·376	1·290	1·288	1·226	1·302	1·365	1·352	1·293
Oxygen	0.641	0·566	0·635	0·586	0·583	0·642	0·598	0·642	0·636
Carbonic acid	0·147	0·143	0·235	0·335	0·322	0·288	0·247	0·220	0·107
Total gases	2·200	2·085	2·160	2·209	2·131	2·232	2·210	2·214	2·036
Other determinations and estimations:									
Ammonia obtained by distilling 100,000 parts of each water with permanganate of potash.	0·009	0·002	0·005	0·001	0·012	0·005	0·012	0·011	0·005
Hardness in 100,000 parts of each water before boiling.	0·9	1·4	1·9	2·1	3·0	2·0	0·7	1·4	0·4
Hardness in 100,000 parts of each water after boiling.	0·9	1·3	1·7	2·1	3·0	2·0	0·7	1·1	0·3
Action on bright lead	Very powerful	Very powerful	None	None	Slight	None	Powerful	None	Very powerful
„ tarnished lead	None	Slight	None	None	Slight	None	None	None	None

Results of Partial Analysis of Welsh Waters.

	Sources of Waters.						
	Tylwch.	Upper Clywedog.	Ceryst.	Banw in flood.	Eira in flood.	Banw and Eira in flood.	Feeders to Bala Lake mixed.
Total solid residue from 100,000 parts of water evaporated and dried at 100° C.	4·80	5·00	9·60	4·14	5·06	4·90	4·10
Mineral substances in 100,000 parts of each water:							
Ammonia	·003	·001	·001	·000	·001	·003	·003
Nitrogen as nitrates and nitrites	·004	·011	·052	·006	·000	·005	·011
Organic substances in 100,000 parts of each water:							
Organic nitrogen	·010	·000	·000	·013	·012	·011	·010
„ carbon	·335	·544	·209	·894	·995	1·040	·311
Other determinations and estimations:							
Ammonia obtained by distilling 100,000 parts of each water with permanganate of potash.	·007	·006	·005	·009	·015	·008	·003
Hardness in 100,000 parts of each water before boiling.	1·15	1·20	2·07	·70	1·40	1·10	1·10
Action on bright lead	Slight	Considerable	Slight	Considerable	Slight	Considerable	None
Action on tarnished lead	None	None	None	None	None	None	None

Results of Complete Analysis of Cumberland Waters.

Names of Substances found.	Sources of Waters. Thirlmere.	Upper Rothay.	Haweswater.	Lower Lowther.	Ullswater.
Total solid residue from 100,000 parts of water evaporated and dried at 100° C.	2·659	3·061	3·559	9·286	3·626
Mineral substances in 100,000 parts of each water:					
Lime	0·361	0·736	0·643	3·096	0·730
Magnesia	0·111	0·166	0·156	0·727	0·200
Potash	0·144	0 063	0·193	0·123	0·267
Soda	0·671	0·404	0·683	0·547	0·356
Sulphuric acid	0·840	1·167	0·020	1·941	0·879
Carbonic acid	0·163	0·350	0·357	2·276	0·310
Silica	0·061	0·221	0·064	0·179	0·140
Chlorine	0·523	0·130	0·539	0·653	0·604
Ammonia	0·003	0·003	0·004	0·002	0·003
Nitrogen as nitrates and nitrites	0·002	0·002	0·000	0·003	0·005
Organic substances in 100,000 parts of each water:					
Organic nitrogen	·004	010	·004	·008	·000
„ carbon	·194	·196	·158	·198	·067
Gases in 100 vols. of each water:					
Nitrogen	1·440	1·310	1·418	1·403	1·551
Oxygen	0·727	0·667	0·739	0·749	0·747
Carbonic acid	0·085	0·227	0·177	0·793	0·185
Total gases	2·252	2·204	2·334	2·945	2·483
Other determinations and estimations:					
Ammonia obtained by distilling 100,000 parts of each water with permanganate of potash	0·005	0·003	0·004	0·002	0·003
Hardness in 100,000 parts of water before boiling	0·7	1·3	1·3	6·7	1·9
„ „ 100,000 „ after boiling	0·7	1·3	1·3	6·3	1·4
Action on bright lead	Considerable	Slight	Considerable	None	Considerable
„ „ tarnished lead	None	None	Slight	None	None

Results of Partial Analysis of Cumberland Waters.

—	Sources of Waters. Feeder to Thirlmere.	Stream from lead work flowing into Thirlmere.	Watendlath Tarn.	Naddle Beck.	Trout Beck (Greta.)	Trout Beck (Greta) in flood.	Mosedale Beck in flood.	Helvellyn Gill.	Measand Beck.
Total solid residue from 100,000 parts of water evaporated and dried at 100° C.	2·75	3·57	3·05	4·05	6·00	5·91	4·90	3·31	2·14
Mineral substances in 100,000 parts of each water:									
Ammonia	·001	·001	·002	·001	·004	·006	·005	·004	·000
Nitrogen as nitrates and nitrites	·003	·018	·006	·010	·001	·015	·006	·003	·000
Organic substances in 100,000 parts of each water:									
Organic nitrogen	·008	·001	·011	·004	·006	·068	·042	·001	·003
„ carbon	·298	·066	·305	·366	·536	1·059	·942	·133	·117
Other determinations and estimations:									
Ammonia obtained by distilling 100,000 parts of each water with permanganate of potash.	·004	003	·003	·004	·004	·020	·020	·003	·000
Hardness in 100,000 parts of water	1·0	·9	1·0	1·3	2·1	2·9	2·0	1·6	2·0
Action on bright lead	Powerful	Powerful	Powerful	Considerable	None	None	Powerful	Powerful	None
„ tarnished lead	None	None	None	None	None	None	None	None	None

(*Continued.*)

—	Sources of Waters. Upper Lowther.	Airy Beck.	Glenridding Beck.	Grisedale Beck.	Goldrill Beck.	Dacre Beck.	Stockgill Beck.	Trout Beck Windermere.	Upper Kent.	River Sprint.
Total solid residue from 100,000 parts of water evaporated and dried at 100° C.	5·10	4·60	6·60	3·77	3·95	13·6	4·48	4·48	3·43	5·83
Mineral substances in 100,000 parts of each water:										
Ammonia	·004	·004	·001	·001	·002	·004	·000	·000	·001	·000
Nitrogen as nitrates and nitrites	·002	·000	·005	·012	·000	·015	·029	·018	·045	·021
Organic substances in 100,000 parts of each water:										
Organic nitrogen	·006	·009	·000	·012	·001	·022	·011	·007	·002	·007
Organic carbon	·263	·259	·116	·157	·262	·328	·128	·125	·319	·130
Other determinations and estimations:										
Ammonia obtained by distilling 100,000 parts of each water with permanganate of potash	·004	·003	·004	·001	·001	·007	·003	·000	·003	·000
Hardness in 100,000 parts of water	2·1	2·1	2·05	2·3	1·6	8·0 after boiling / 3·75	2·3	1·80	1·2	2·9
Action on bright lead	None	Very slight	Considerable	Slight	Considerable	None	Slight	None	Powerful	None
Action on tarnished lead	None	None	None	None	None	None	None	None	None	None

Additional Observations by Dr. Frankland.

In connexion with the various analytical determinations contained in the above tables, the following additional explanations and observations are offered:—

I.—Total Solid Residue.

Apart from the quality of the ingredients contained in potable waters, the proportion of solid residue left on evaporation is a rough indication of the comparative purity of such waters; for, although in cases where this residue is considerable, it by no means follows that a sample with a smaller amount is, for domestic purposes, superior to one containing a larger quantity, yet it may be safely asserted that waters leaving large residues on evaporation are unfit for domestic use, whilst those containing very small residues are, on this account alone, well adapted to such purposes, and but very rarely contain amongst their impurities any which are seriously objectionable. Besides their general superiority for domestic purposes, waters leaving small residues on evaporation possess great advantages over less pure waters for a large number of manufacturing purposes, especially for feeding steam boilers are the purer waters invaluable, as their use precludes the formation of incrustations which not only seriously interfere with the transmission of heat from the fuel to the water, but are believed to be not unfrequently the cause of disastrous explosions.

The Welsh Waters leave on evaporation residues which vary from a minimum of 3·37 parts in 100,000 to a maximum of 9·6 parts in 100,000. It must be remarked, however, that this maximum is attained only in the case of a small stream (the Ceryst) running, at the time of collection, only about 3,000,000 gallons per day, and fouled by much suspended matter from the Fan mine. In a storage reservoir this suspended matter would subside, and the resulting clear water would doubtless leave considerably less solid residue on evaporation. This remark will also apply to the united waters of the Tarannon and Ceryst, containing 6·4 parts of solid residue in 100,000 parts of water.

On the other hand, the water of the Lower Clywedog, running 20,000,000 gallons daily, contains 8·1 parts of solid residue in 100,000 parts, and, being clear when collected, would not deposit much of this matter on standing in a reservoir, but although the residue is large when compared with the purest samples from the proposed gathering grounds, it nevertheless compares favourably with the waters at present supplied to London, which leave on evaporation solid residues varying during the year 1866 from 20·2 to 40·4 parts in 100,000.

The Cumberland and Westmoreland Waters leave on evaporation residues varying from a minimum of 2·14 parts to a maximum of 13·6 parts in 100,000; this maximum, however, is exhibited by a sample (the Dacre Beck) which stands alone as regards impurity amongst the waters of this district. Its exceptional character has already been pointed out by Mr. Pole in his report on the collection of the samples, and the analytical results support his recommendation that this beck should be excluded from Messrs. Heman's and Hassard's scheme.

Omitting this sample, the next as regards amount of residue is that taken from the Lower Lowther, which contains 9·29 parts of solid matter in 100,000 parts of water; but the Lower Lowther is intended to be used chiefly for compensation water, and Mr. Pole has pointed out a modification of the proposed conduits, by which, whilst the purer water of the Upper Lowther (containing only 5·1 parts of residue in 100,000) would be utilized, the lower part of the river would be altogether excluded from the scheme. Although the water of the Lower Lowther is by no means of bad quality, yet it is so much inferior to the remaining sources of this district as to fully justify Mr. Pole in considering its exclusion desirable. If we omit this sample and also leave out of consideration the milky stream which flows from the Glenridding lead mines, the maximum amount of solid residue occurs in the Troutbeck (Greta) water, which contains 6 parts of solid residue in 100·000 parts. With the exceptions just mentioned, therefore, the waters of the Cumberland and Westmoreland district leave a smaller residue on evaporation than those of the Welsh district. The residues left by the waters of the three great lakes included in the Cumberland scheme are remarkable for their insignificance, viz.:—

Thirlmere	- -	2·66 parts in 100,000
Haweswater	- -	3·56 „
Ullswater	- -	3·63 „

The storage of waters in large lakes or reservoirs appears, as a rule, to diminish the proportion of solid residue as compared with that contained in the feeders of such lakes. Unfortunately in Mr. Bateman's district there is no such lake, and we are thus deprived of a fair basis of comparison between the quality of the water now stored in the three Cumberland lakes and that of the water which would be delivered from the large reservoirs contemplated in Mr. Bateman's scheme. On this account we have examined the water of the Bala Lake and its feeders, which, although just outside Mr. Bateman's district, drain the same geological formation as the northern Welsh district. A comparison of the solid residue of the feeders of this lake with that of the water of the lake itself not only exhibits the purification effected in lakes and reservoirs but also indicates that the Welsh water, after storage, would not be inferior in purity, as regards solid residue, to that of the Cumberland lakes. The residues in the waters of Bala Lake and its feeders are as follow:—

Bala Lake	- -	2·79 parts in 100·000
Average of four feeders of ditto	- -	4·10 „

So far, therefore, as total solid residue is concerned, the above analytical results promise a water supply from either district fully equal in purity to that of any town in the United Kingdom.

II.—The Mineral Constituents.

The solid residue left on the evaporation of potable waters consists partly of mineral and partly of organic matters. Unless the amount of residue be considerable but few of the individual mineral constituents are of much interest, we have, therefore, only submitted the more important samples of water to the searching investigation required for the separate determination of each of these constituents. Of the mineral matters met with in potable waters those belonging to the following three classes claim our chief attention.

1. Substances which decompose soap.
2. Substances which are more or less derived from the decomposition of nitrogenous organic matters previously existing either in the water or in the soil with which the water has been in contact.
3. Substances of a poisonous character, such as compounds of the metals, arsenic, copper, and lead.

The first class of mineral matters above enumerated consists of the hardening or soap destroying constituents of waters. The chief substances of this class are the salts of lime and magnesia. These salts decompose soap, forming curdy and insoluble compounds, containing the fatty acids of the soap and the lime and magnesia of the salts. So long as this decomposition goes on the soap fails to produce a lather, and is consequently useless as a detergent; but when all the lime and magnesia salts have been decomposed by the soap, the slightest further addition of the latter produces a lather when the water is agitated. In the above tables the hardness of the different samples of water is expressed in parts of carbonate of lime, or of its equivalent of other hardening salts, contained in 100,000 parts of the water, each part of carbonate of lime contained in this quantity of water being commonly termed a degree of hardness.* Each degree of hardness indicates the destruction of about 12 parts of the best hard soap by 100,000 parts of water. Hard water is, however, not only objectionable from an economical point of view, but by rendering efficient ablution and thorough cleanliness difficult of attainment, it doubtless indirectly affects the health of communities to which it is supplied. From the well-known action of hard water upon soap, the process of washing the skin with such water may be thus described. First, the skin is wetted with the water, then soap is applied; the latter soon decomposes all the hardening salts contained in the small quantity of water with which the skin is covered, and there is then formed a strong solution of soap which penetrates into the pores of the cuticle. Such is the process which goes on whilst a lather is produced in washing, but now the lather requires to be removed by rinsing it away with water, and in this operation the pores of the skin become plugged up with the curdy matter which results from the action of the hard water upon the soap solution occupying those pores. The operation of washing with soap and hard water is thus analogous to that used by the dyer or calico printer when he wishes to fix a pigment upon any tissue. He first introduces into the tubes of the fibre (of calico, for instance) a liquid, containing in solution one of the ingredients necessary for the formation of the insoluble pigment, this is followed by another liquid containing the remaining necessary ingredient also in solution; the insoluble pigment is then produced within the very tubes of the cotton fibre, and is thus imprisoned in such a manner as to defy removal by subsequent washing. The process of ablution in hard water is essentially one of dyeing the skin with the white insoluble, greasy, and curdy salts of the fatty acids contained in the soap. The pores of the skin are thus more or less blocked up, and it is only

* The degree of hardness more usually employed by chemists is that first proposed by Dr. T. Clark, viz., one grain of carbonate of lime, or its equivalent in one imperial gallon of water or one part in 70,000 of water. The degrees in the above table harmonize better with the decimal arrangements of the rest of the analytical results; they are readily converted into Clark's degrees by multiplying by seven, and then moving the decimal point one place to the left.

because the insoluble pigment produced is white that such a repulsive operation is tolerated. To those, however, who have been accustomed to wash in soft water the abnormal condition of the skin thus induced is for a long time extremely unpleasant.

In the year 1851 this subject received the careful consideration of a Government Commission, consisting of the present Master of the Mint, Dr. W. A. Miller, and Dr. A. W. Hofmann.* I entirely agree with these chemists in their condemnation of hard waters for the supply of towns, and beg to refer to their report for the grounds upon which this condemnation is based. Having had the opportunity of comparing a six years' experience of the soft water supplied to Manchester with a subsequent 10 years' experience of the hard water of London, I have to record that the soft water was, for all purposes, preferred by every member of my family. On removing from Manchester to London, the repugnance to drink the hard water of the latter city, even though filtered, was quite as marked as that which I have sometimes noticed in the case of persons who make the transition in the opposite direction. Moreover, when water is excessively hard from the presence of carbonates of lime and magnesia, a portion of these salts is deposited on exposure to the air, and the water reaches the consumer milky and turbid. This is frequently the case with the chalk waters delivered in London. A constant supply of hot water has become almost a necessity in every household, but great difficulties are thrown in the way of its attainment by the use of hard water, owing to the formation of thick calcareous crusts in the heating apparatus. This evil is so great where the heating of the water is effected in a coil of pipe, as practically to prevent in London the use of this most convenient mode of heating water. The water in my kitchen was for several years heated in this way, but it was found that three months' use sufficed to deposit so much calcareous matter in the pipe as to reduce the bore of the latter to $\frac{1}{4}$th inch. The coil had, therefore, to be taken to pieces at intervals of three months, and the hard deposit removed by a tedious and expensive process, which, moreover, so far injured the copper pipe itself as to render its frequent renewal necessary.

An inspection of the above analytical tables shows that the samples of water both from the Welsh and Cumberland districts are very soft, being, generally speaking, of about the same degree of hardness as those supplied to Manchester and Glasgow. Leaving out of consideration, for reasons above given, the water from the Dacre Beck in Cumberland, which has 8° of hardness, and from the Lower Lowther, the following table gives the comparative hardness of the Welsh, Cumberland, and London waters:—

	Maximum.	Minimum.
	°	°
Welsh waters - - -	3·0	0·4
Ditto, exclusive of Bala Lake -	3·0	0·7
Cumberland waters - -	2·9	0·7
London - - - -	28·8	14·4

The hardness of the London waters is chiefly of the kind known as *temporary* hardness; it is caused by carbonate of lime, the larger proportion of which is gradually deposited on boiling the water for half an hour. The temporary hardness of the London waters varies from 9·9° to 19·1°, whilst the *permanent* hardness (that is the hardness remaining after boiling for half an hour) oscillates between 3·4° and 9·7°. On account of this softening of temporarily hard water by boiling, temporary hardness is considered to be less objectionable than the same amount of permanent hardness. There is reason to believe, however, that the advantages of temporary over permanent hardness have been considerably overrated. Practically, water used for domestic purposes is, even when used hot, either not heated to the boiling point, or is boiled for too short a time to remove more than a small proportion of its temporary hardness. Thus, water drawn from the kitchen boilers of a dwelling house and of the Athenæum Club was usually nearly as hard as the cold water with which they were supplied, as is seen from the results of the following experiments:—

Date and Hour.	Hardness of cold Water	Hardness of hot Water.
	°	°
September 30th, 1867, 8 p.m. - -	14·6	13·6
October 1st „ 8 p.m. - -	14·4	13·9
„ 2nd „ 8 a.m. - -	14·4	13·4
„ 3rd „ 9 p.m. - -	14·6	11·6
„ 4th „ 8 a.m. - -	14·6	7·6
„ 7th „ 8 p.m. - -	14·4	11·7
„ 8th „ 8 a.m. - -	14·4	12·1
„ 9th „ 8 p.m. - -	15·4	14·3
„ 10th „ 8 p.m. - -	15·9	11·9
„ 11th „ 8 a.m. - -	15·9	8·4
„ 12th „ 8 a.m. - -	16·1	11·9
November 8th „ 5 p.m. - -	18·7	18·4
„ 11th „ 5 p.m. - -	18·7	18·6
„ 12th „ 6 p.m. - -	18·7	18·4

* Report by the Government Commission on the chemical quality of the supply of water to the metropolis.

It has been objected with reference to the use of soft water that such water is liable to attack and dissolve the lead of the pipes through which it is conveyed, or of the cisterns in which it is stored; and secondly, that soft water would exclude from the diet of its consumers the calcareous matter necessary for the formation and renewal of the bones.

Reasons are given below for concluding that, as regards the first of these objections, no fear of lead contamination need be entertained from the introduction either of the Welsh or Cumberland waters into London. The second objection to the use of soft water is equally fallacious; first, because the amount of lime contained in the water at present drunk by an inhabitant of the metropolis is only a minute fraction of that which he takes in other articles of food and drink; and secondly, because observation and experience show that hard water is not necessary to a full development of bone in man. It cannot be said that the stalwart natives of the soft water districts of the Highlands of Scotland are deficient in bony development.

The second class of mineral constituents above mentioned consists of substances derived partly from the atmosphere and partly from the decomposition of nitrogenous organic matters previously existing either in the water or in the soil with which the water has been in contact. In view of the opinions now very generally entertained, with regard to the propagation of certain forms of disease by means of spores or germs contained in excrementitious matters, the search for this class of impurities is second only in importance to that for actual sewage contamination, because, although these substances are in themselves innocuous, unless present in excessive quantity, yet, when contained in a water in more than a certain proportion, they betray the previous contamination of the water by sewage or by manured land. The nitrogenous organic matters contained in sewage or manure undergo slow oxidation, and conversion into mineral compounds when mixed with water; their carbon is converted into carbonic acid, and their hydrogen into water. These products can no longer be identified in the aërated waters of a river, spring, or lake, but the nitrogen is transformed successively into ammonia, nitrous acid, and nitric acid; the two latter combine with the bases contained in most waters, and, together with the ammonia, constitute a record of the sewage or other analogous contamination to which the water has been subject. With certain corrections presently to be mentioned, the analytical determination of the nitrogen contained in these mineral compounds furnishes the previous history of the water as regards its contact with decomposing nitrogenous organic matters. In the monthly reports furnished by me to the Registrar General on the Metropolitan water supply this determination has been employed for the estimation of the previous sewage contamination of a water, expressed in parts of average filtered London sewage, which, if thus completely oxidised in a river, would yield a like amount of nitrogen in the form of ammonia, nitrites, and nitrates. For this purpose average filtered London sewage may be taken as containing 10 parts of combined nitrogen in 100,000 parts, as deduced from the numerous analyses of Hofmann and Witt, and of Way and Odling. The number so obtained as the previous sewage contamination of a water requires, however, a correction, since rain-water itself contains combined nitrogen as ammonia, nitrite of ammonia, and nitrate of ammonia. The amount of these substances present in the rain which falls at Rothampstead has been determined by a series of monthly analyses made independently, on the one hand by Messrs. Lawes and Gilbert, and on the other by Professor Way, and extending over two years. The results of these chemists give as the average amount of nitrogen in the forms of ammonia, nitrite of ammonia, and nitrate of ammonia, ·0985 part in 100,000 parts of rain-water. This corresponds to 985 parts of previous sewage contamination, which has hitherto been deducted from the previous sewage contamination of the London waters, as determined by analysis. But the experience gained in the examination of the Welsh and Cumberland waters teaches that this deduction is far too large. The maximum amount of ammonia contained in the 42 samples of water examined by us is only ·008 part in 100,000, whilst the average amount of nitrogen in the form of nitrous and nitric acids observed by Messrs. Lawes, Gilbert, and Way, and this in thunder rain only, was but ·024 part in 100,000. It may, therefore, be safely assumed that the maximum amount of combined nitrogen, derived by natural waters from aërial sources, does not exceed ·024 + ·008 = ·032 part in 100,000, which gives the number 320 to be deducted from the previous sewage contamination as determined by analysis.

Absolutely pure water is unknown in nature, for, as just stated, even rainwater is contaminated, and its descent down the precipitous slopes of the Welsh and Cumberland mountains cannot fail to bring it into contact with the droppings of sheep, cattle, and birds. The amount of impurity so contracted is, however, infinitesimal, but when

ıe water receives the drainage from cultivated land, the ·sidues of oxidised nitrogenous organic matters become im-ıediately appreciable to chemical analysis. Thus the stream ›rmed by the junction of the Tarannon and Ceryst, hich Mr. Pole describes as traversing a flat expanded alley, exhibits unmistakeable signs of previous sewage ntamination, for it contains no less than ·068 part of trogen in the form of nitrates and nitrites, corresponding, cording to the mode of corrected estimation just given, to 60 parts of oxidised London sewage in 100,000 parts of ıe water.

The amount of nitrogen contained in the Welsh waters the form of ammonia, and of nitrites and nitrates, only ceeds the amount contained in rain-water in the following ses:—

	Nitrogen in the form of ammonia, and of nitrites and nitrates in 100,000 parts.	Corresponding previous sewage contamination in 100,000 parts.
ıarannon and Ceryst	·068	360
eryst - -	·053	210
arno - -	·051	190

ut of 24 samples from the Cumberland district only one ntained these mineral compounds of nitrogen in quantity ger than that found in rain-water; this was the sample llected from the Upper Kent, which contained ·046 part nitrogen in the form of ammonia, and of nitrates and trites in 100,000 parts, corresponding to 140 parts of pre-ous sewage contamination in 100,000 parts. The follow-g table extracted from the reports of the Registrar General ows the condition of the present metropolitan water pply as regards these mineral compounds of nitrogen, d the previous sewage contamination thereby indicated. is table contains the maximum and minimum analytical sults for the months of June, July, August, September, d October last, the estimations of previous sewage con-mination being corrected, as above described, by the duction of the number 320 instead of 985.

	Nitrogen in the Form of Ammonia, and of Nitrites and Nitrates in 100,000 Parts.		Corresponding previous Sewage Contamination in 100,000 Parts.	
	Maximum.	Minimum.	Maximum.	Minimum.
Thames.				
elsea - - -	·218	·189	1,860	1,570
est Middlesex - -	·311	·137	2,790	1,050
athwark and Vauxhall	·227	·145	1,950	1,130
and Junction - -	·324	·137	2,920	1,050
mbeth - - -	·281	·168	2,490	1,260
Other Sources.				
w River - -	·328	·161	2,950	1,330
st London - -	·200	·055	1,700	230
nt - - -	·499	·320	4,220	2,890

A comparison of this table with the corresponding deter-inations in even the worst of the Welsh and Cumberland aters shows the striking superiority of the samples from ıe last two sources. The unfavourable position which ıe Kent Company's water takes in this comparison is markable, since this water is derived from wells sunk to the chalk, and might therefore be presumed to be ore than usually free from contamination of this kind; ut the phenomenon excites less surprise when it is membered that the chalk of the London basin receives large amount of soakage from cultivated land; secondly, ıat the chalk wells of Woolwich Arsenal betray symp-oms of connexion with the river Thames; and, thirdly, ıat the chalk itself is, according to the recent researches f Bechamp, filled with living microscopical organisms. he presence of large quantities of nitrates in the chalk aters of the Kent Company is by no means exceptional; ese salts exist in still larger quantity in the chalk waters f Grays (South Essex Company's water), Worthing, and Vatford. Mr. Dugald Campbell states that the water of ıe shallow chalk wells invariably contains a notable uantity of nitrates, whilst that of the deep chalk wells ontains scarcely a trace.

The third class of mineral substances, viz., those of a oisonous character, such as compounds of the metals rsenic, copper, and lead, have been carefully searched for ı those waters which are contaminated by mineral orkings. In only three cases have we been able to etect any of these impurities, viz., in the Glenridding eck, the stream from lead-works flowing into Glenridding eck, and the stream from lead-works flowing into Thirl-ıere, which contain lead, but in such excessively minute uantity as to allay any apprehensions of injurious conse-uences resulting from the admission of these waters into he lakes or reservoirs. Indeed reasons are given below for trongly recommending that these streams from mineral orkings should not be diverted, but, under certain restric-ions, be freely admitted into the storage waters.

III.—The Organic Constituents.

Of all the impurities present in potable waters organic matters are admitted on all hands to possess, from a sanitary point of view, the highest importance and most especial interest. These substances may be divided into two great classes, viz., 1st, organized organic matters, and 2nd, unorganized organic matters. The detection and identification of the first of these classes does not properly belong to the province of the chemist; considering the superlative importance, however, with which it is generally regarded in connexion with the propagation of certain forms of disease, it is singular that it should have hitherto received so little attention from the naturalist, and that, notwithstanding the strong and general suspicion of their existence, no animal or vegetable germs connected with the production of disease in man have been identified in water. It is obvious that all organized organic matters in water must be in suspension and not in solution, but it by no means follows that such matters can therefore be removed by filtration. The minute ova of animalcules have been observed to pass through filters, and it has been proved* that the suspended matter in the rice-water evacuations of cholera patients cannot be removed by filtration from water which has become contaminated with such matter. These facts, together with the certainty that dilution with large volumes of water does not, as in the case of unorganized substances in solution, render organized germs innocuous, acquires great significance in view of the prevalent theories of the propagation of cholera, typhoid fever, and other diseases.

The class of unorganized organic impurities in potable waters is much more amenable to chemical research, and has in fact always attracted the special attention of the water analyst. Speaking of these substances in their report to the President of the General Board of Health, on the Metropolis Water Supply in 1856, Messrs. Hofmann and Blyth made the following important remarks (p. 5): "It is "now generally admitted, that the substances which con-"stitute the organic matter of water act injuriously by no "means in consequence of being poisonous themselves, "but by undergoing those great processes of transforma-"tion called decay and putrefaction to which all vegetable "and animal matter is subject when no longer under the "control of vitality, either in plants or animals. These "putrefactive processes either give rise to the formation of "poisonous bodies, or they act simply as ferments, genera-"ting similar processes of decomposition in the substances "composing the animal organism. Now with special refe-"rence to the last mode of action, it is well established by "general experience that *nitrogenous* substances are infi-"nitely more liable to undergo putrefaction than organic "bodies from which nitrogen is absent. And hence the "very general and correct opinion that the deleterious "character of organic matter in water is proportionate to "the amount of *nitrogen* which it contains. Could this "nitrogen be estimated with any degree of accuracy, such "an estimate would certainly afford the most satisfactory "element in the examination of organic matter." At the time the above remarks were written no method of making this estimation of nitrogen was known; indeed, it is only quite recently that the process which we have employed for the determination both of organic nitrogen and of organic carbon was devised.

The Welsh Waters contain an amount of organic carbon which varies from ·200 part in 100,000 parts of the water of the Severn to 1·040 part in 100,000 in the flood waters of the united rivers Banw and Eira. All the samples which contain more than ·35 part of organic carbon in 100,000 are, with the exception of the upper Clywedog, more or less coloured, and they are all, with the same exception (the upper Clywedog, running at the time of collection 2,000,000 or 3,000,000 gallons daily) flood samples. The colour is doubtless due to peaty matter in solution, and it is believed that such peaty matter is to a great extent deposited or otherwise got rid of when the water is stored for some time in a lake or resevoir. This opinion receives confirmation from the above results of the analyses of lake waters, all of which are colourless, or very nearly so, and contain only a small amount of organic carbon; thus the water of the Bala Lake contains but ·227 part of organic carbon in 100,000 parts, whilst the waters of Thirlmere, Haweswater, and Ullswater contain at the maximum only ·194 part in 100,000. On the other hand, when the amount of peaty matter in solution is excessive, this purification in lakes does not appear to take place to a marked extent; thus, the water which flows out of Loch Ness is of a deep yellow brown colour, and numerous other Scotch lakes might be cited as exhibiting the same phenomenon. Although the peaty matter dissolved in water cannot be said to be positively injurious, yet, inasmuch as it contains traces of organic nitrogen, it cannot be pronounced absolutely innocuous.

* Weekly return of the Registrar General for the week ending 17th November 1860.

The amount contained in the water of Loch Katrine as supplied to Glasgow, and which is represented by ·256 part of organic carbon in 100,000 parts, ought not to be greatly exceeded in water used for domestic purposes.

The organic nitrogen contained in the Welsh waters varies from 0 to ·013 part in 100,000 parts, the latter proportion occurring in the flood water of the Banw. The other samples from this district which exhibit a somewhat high proportion of organic nitrogen are flood samples from the Eira, and from the combined streams Banw and Eira ·012 and ·011 part in 100,000. The mixed waters of four feeders of Bala Lake also contained ·010 part in 100,000. Judging from the effect of the storage of water in Bala Lake in diminishing organic nitrogen, it may be anticipated that the combined waters of this district when delivered from the proposed reservoirs would not contain more than ·005 part of organic nitrogen in 100,000, and would probably contain less, for the Bala Lake contains only ·001 part, although the united waters of its four principal feeders yield no less than 10 times this proportion.

In addition to the organic nitrogen as thus determined by direct analysis we have also estimated the amount of ammonia which is evolved from the waters by prolonged ebullition with a strongly alkaline solution of permanganate of potash, the ammonia previously existing in the water being first expelled by ebullition with carbonate of soda. This method has been recently proposed by Messrs. Wanklyn and Chapman as a means of determining the organic nitrogen in waters. In our hands this process has yielded somewhat irregular results. As a rule, which is however by no means without exceptions, the organic nitrogen so inferred is considerably less than that obtained by direct analysis, and this is markedly the case with those waters which contain a comparatively large amount of organic nitrogen; thus, the flood water of Troutbeck (Greta) gave us by analysis ·068 part of organic nitrogen, whilst the same water when boiled with alkaline permanganate gave only ·016 part. Whilst therefore this process is valuable as a ready qualitative method of ascertaining the presence of organic nitrogen in waters, we do not think that, in its present form, it can be relied upon for the determination of the actual amount of this element.

The Cumberland Waters contain an amount of organic carbon which varies from ·066 part to 1·059 part in 100,000. It will thus be seen that whilst the minimum proportion of this element is much smaller than that contained in the Welsh waters (·200 part in 100,000), the maximum is almost identical, and also occurs in a flood sample. With this and one other exception, however, the Cumberland waters contain markedly less organic carbon than the Welsh samples; but, in making this comparison, it must be borne in mind that out of 24 samples of Cumberland water only two were flood samples, whilst out of 16 samples from Wales four were flood samples. Excluding these flood samples in both cases, the mean proportion of organic carbon in the samples from the two districts, independently of the flow of the streams, is as follows:—

Welsh waters	·289
Cumberland waters	·211

The organic nitrogen contained in the Cumberland waters varies from 0 in Ullswater lake and Glenridding Beck to ·068 part in 100,000 in the flood water of Troutbeck (Greta). The Mosedale Beck in flood also contains ·042 part in 100,000. In his report on the collection of the last two waters, Mr. Pole, judging only from the appearance of the streams, suggests their rejection from the scheme; our analytical results strongly confirm this suggestion. Excluding the flood samples of both districts, and leaving out of consideration as before the volumes of water from which the samples were taken, the average proportion of organic nitrogen in the specimens from the two districts is—

Welsh waters	·004
Cumberland waters	·006

It is a remarkable circumstance that the waters of the Cumberland district which are described by Mr. Pole as contaminated by mineral workings, at the time of collection, contain but very small proportions both of organic carbon and nitrogen. Thus, the milky water flowing down Glenridding Beck from the extensive leadworks on the flanks of Helvellyn contained but ·116 part of organic carbon, whilst it was absolutely free from organic nitrogen. An inspection of the following numbers shows at a glance the extreme purity as regards organic matter of the streams containing milky water from the crushing engines of mines:—

	Organic carbon.	Organic nitrogen.
Glenridding Beck	·116	·000
Steam from leadworks flowing into Thirlmere	·066	·001
Goldrill Beck	·262	·001

In the Welsh district the small proportion of organic carbon in waters flowing from mineral workings is not so evident, but the amount of organic nitrogen is remarkably low. The only samples which at the time of collection were actually receiving the finely-suspended matter from this source were the following:—

	Organic carbon in 100,000 parts.	Organic nitrogen in 100,000 parts.
Ceryst	·209	·000
Upper Clywedog	·544	·000
Lower „	·242	·001
Tarannon and Ceryst	·304	·001

The water of the Upper Clywedog, though containing as much as ·544 part of organic carbon in 100,000 parts, is perfectly colourless, the peaty matter in solution having been apparently blanched by the fine suspended detritus from the Dwngwm lead mine. This removal of colouring matter from water by fine suspended mineral matter is seen on a magnificent scale in Switzerland, where Alpine torrents carrying the fine mud produced by the attrition of glaciers upon rocks, enter the lakes milky and foul, but, having deposited their suspended matter in these reservoirs of subsidence, emerge clear and transparent, and of that magnificent blue-green tinge (properly belonging to absolutely pure water) which is so much admired in the Rhone as it flows from the Lake of Geneva, and in the Limmat leaving the Lake of Zurich. An observant tourist cannot fail to remark striking indications of this clarifying action in the lakes of Ullswater and Coniston. The blue-green tint of water freed from colouring matter is distinctly perceptible for several miles around the mouths of the streams coming down from the Glenridding leadworks, in the one case, and from the extensive mines in Coniston Old Man in the other. I consider, therefore, that, so far from the diversion of these streams being desirable, their admission into the lakes and reservoirs would be attended with very considerable advantages, in the removal of peaty matter from the storage water.

It has been already stated that even in cases where we have detected lead in these milky streams, the amount is so infinitesimal as to allay the apprehensions of the most fastidious as regards any deleterious effect upon the consumer of the water with which these streams are allowed to mingle. The finest portion of this detritus doubtless possesses the most active clarifying effect, and it is, therefore, desirable, as recommended by Mr. Pole, that the grosser particles, which would silt up the reservoirs without producing any correspondingly beneficial effect, should be separated in subsiding tanks, and, it need scarcely be added, that care should be taken to prevent the excretions of the miners from gaining access to these streams.

In order to ascertain the effect of an admixture of milky water from mineral workings with a water strongly coloured with peaty matter, the deep yellow flood water of the Banw and Eira was agitated with an equal volume of the Glenridding Beck water. The deep yellow of the peaty water was very materially diminished beyond the mere effect of dilution, and on evaporation the residue was of a light yellow colour, whilst that of the flood sample alone was dark brown.

IV. The Gaseous Constituents.

The gaseous constituents contained in the waters, both of the Welsh and Cumberland districts, are of the kind usually found in good soft potable waters, which invariably contain a smaller proportion of gases than is met with in hard waters abounding in carbonates of lime and magnesia. The latter frequently retain, by the chemical affinity of their dissolved salts, a larger amount of carbonic acid than they could absorb by the process of solution alone. In fact, the carbonic acid thus chemically united with the carbonates of lime and magnesia can scarcely be said to be in the state of merely dissolved gas, although it is expelled along with the actually dissolved gases on the prolonged ebullition of the water. Recently distilled water contains about the following amounts of dissolved gases in 100 volumes:—

Nitrogen	1·133
Oxygen	·617
Carbonic acid	·105
	1·855

Collected near the great natural condensers, the waters of both Wales and Cumberland contain, as might be expected, but little more air in solution than recently distilled water. In their long transit to London, however, they would doubtless become much better aërated, but even then they would contain a much smaller proportion of carbonic acid than the waters at present supplied to the metropolis, and would consequently appear less sparkling

an the latter. Sparkling waters, highly charged with rbonic acid, are generally preferred by the public, even en they owe their briskness to extensive contact with caying organic matter. On the other hand, it is not true at soft waters are necessarily vapid; no draught of water n be more delicious than that which is obtained from the blic drinking fountains of Glasgow, supplied from Loch trine, although 100 volumes of this water contain, as I ve ascertained, only the following gaseous constituents:—

Nitrogen	1·731
Oxygen	·704
Carbonic acid	·113
	2·548

The Welsh Waters contain in 100 volumes the following portions of the same gases, viz.:—

	Minimum.	Maximum.	Mean.
trogen	1·226	1·412	1·323
ygen	·566	·642	·612
rbonic acid	·107	·335	·227
	1·899	2·389	2·162

In waters which are free from putrescent organic matters e proportion of oxygen to nitrogen in the dissolved gases ght to be nearly as 1 : 2. In the Welsh waters the proion varies from 1 : 2·03 in the Bala Lake water to 2·43 in the Lower Clywedog.

The Cumberland Waters contain in 100 volumes the lowing proportions of gases, viz.:—

	Minimum.	Maximum.	Mean.
trogen	1·310	1·551	1·424
ygen	·667	·749	·726
rbonic acid	·085	·793	·281
	2·062	3·093	2·431

The proportion of oxygen to nitrogen varies from 1 : 1·87 the Lower Lowther to 1 : 2·08 in Ullswater. The Cumrland waters are therefore somewhat better aërated than e Welsh samples, and they also exhibit a higher proporon of oxygen to nitrogen.

V. Action upon Lead.

We have ascertained carefully the behaviour of every mple of water in contact both with bright and clean lead d with the metal in that tarnished condition which it asmes after exposure for a few days to the atmosphere. The sults of our observations, which are contained in the preding analytical tables, prove conclusively that soft waters o not necessarily act upon lead, and that whilst many of ie samples examined by us attack the metal when its surce has been recently scraped, comparatively few have any ction upon the tarnished metal, and probably none would ttack the leaden pipes through which any of the waters at resent supplied to London have been transmitted.

The conditions which determine the character of water as egards its action upon lead have hitherto been involved in uch obscurity, notwithstanding that they have repeatedly een the subject of investigation. The Government Comission of 1851 on the water supply of the metropolis stablished the fact that the presence of dissolved oxygen nd the absence of more than three volumes of carbonic cid in 100 volumes of water, are amongst the conditions ecessary to cause the water to attack lead. The whole of he present water supply to the metropolis is perfectly proected from acting upon lead by the large amount of disolved and combined carbonic acid which it contains. Nevertheless, there are obviously other conditions involved n the problem, for every sample of water, the gases from vhich we have examined, from both districts contains disolved oxygen, and the proportion of this gas existing in he different samples is remarkably uniform, whilst not one of them contains an amount of carbonic acid even remotely pproaching that which is necessary to protect it, and yet ome of these waters act powerfully upon bright lead, and onsiderably upon the tarnished metal, whilst others are ntirely without action upon either.

In the course of some recent experiments upon this subect, the writer observed that a sample of distilled water vhich acted violently upon lead completely lost this power by momentary contact with animal charcoal; further investigation of the cause of this phenomenon, proved the protecting material to be phosphoric acid which is contained in the animal charcoal in the form of phosphate of lime. Acting upon the suggestion afforded by these experiments, he has very carefully examined for phosphoric acid the water of the Upper Kent which is eminently distinguished for its violent action upon lead, and the water of the river Vyrnwy which has not the slightest action upon lead even when placed in contact with a bright and freshly cut surface of the metal for 24 hours. The result of this examination established the fact that the water of the Vyrnwy contained an appreciable amount of phosphoric acid, whilst not the slightest trace of this acid could be detected in that of the Upper Kent. It has also been ascertained that the admixture of an equal volume of the Vyrnwy water with that of the Upper Kent greatly reduced, although it did not altogether prevent its action upon the bright metal. The compounds of phosphoric acid are therefore obviously eminently efficient in protecting water from action upon lead, and whenever such action is feared, the foregoing facts point to a most simple and efficient remedy, viz.:—the passage of a certain proportion of the water through animal charcoal. As the merest trace of the phosphate of lime is dissolved by the water, the hardness of the latter is not thereby sensibly increased. It may, however, be confidently stated that no danger on this score need be apprehended from the introduction of water from either district into the metropolis, as it will be seen that but a very small number of the waters act upon tarnished lead—a condition of the metal which soon ensues in new lead pipes. Unquestionable as the reasons for this conclusion appear to be, it is satisfactory to find them supported by many years experience on a large scale. Amongst the waters which we have examined from both districts there is not one which acts more powerfully upon lead than that supplied to Glasgow from Loch Katrine, and yet it is believed that no symptoms of lead poisoning have ever been observed in that city since its introduction seven years ago. It has been sometimes stated that although the Loch Katrine water acts powerfully upon bright lead it does not attack tarnished lead, and also that whilst the water acts violently upon lead as it issues from the lake, it loses this power during its transmission through some 25 miles of conduit on its way to Glasgow. Neither of these statements accords with the writer's own experience. He has examined samples taken nearly simultaneously from the lake and at Glasgow and finds that both samples act with equal energy, and attack both bright and tarnished lead. It is thus evident that even a water of this character can be safely delivered to a large community. Probably the lead pipes are slightly acted upon at first, but a protecting film soon coats their inner surfaces and prevents further attack. This is known to be the case at Manchester where the water acts slightly upon new pipes, but the action soon ceases.

The Welsh Waters may be classified in regard to their action on lead as follows:—

	Action on bright lead.
3 samples	Very powerful.
1 „	Powerful.
3 „	Considerable.
4 „	Slight.
5 „	None.
	Action on tarnished lead.
2 samples	Considerable.
14 „	None.

The Cumberland Waters may in the same way be thus classified:—

	Action on bright lead.
6 samples	Powerful.
6 „	Considerable.
4 „	Slight.
8 „	None.
	Action on tarnished lead.
1 sample	Slight.
23 samples	None.

In conclusion, it only remains to compare the results of the foregoing analyses with those yielded by the waters at present supplied to the metropolis, and in order to facilitate the comparison on the present as well as on future occasions, it will be convenient to throw the data into the form in which they are expressed in my monthly reports on the metropolitan waters published by the Registrar General. The numbers for the London waters are taken from the reports for May, June, July, August, September, and October last. The waters supplied to Glasgow, Manchester, and Lancaster are also included in the comparison.

	Total Solid Impurity.			Organic Carbon.			Organic Nitrogen.			Ammonia.			Nitrogen as Nitrates and Nitrites.			Total combined Nitrogen.			Estimated previous Sewage Contamination.			Total Hardness.		
	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.
Thames water delivered by the Chelsea, West Middlesex, Southwark, Grand Junction, and Lambeth companies.	29·84	23·70	26·78	1·020*	·170	·275	·082*	·000	·011	·120*	·001	·007	·319	·136	·192	·421*	·140	·213	2,920	1,050	1,751	21·4	16·0	19·3
River Lea water delivered by the New River Company.	26·60	23·21	24·35	·217	·115	·149	·007	·000	·002	·006	·001	·002	·322	·160	·221	·327	·165	·234	2,950	1,330	2,013	19·1	16·3	18·2
Ditto, delivered by the East London Company.	27·22	23·30	25·67	·245	·133	·180	·015	·000	·006	·006	·001	·002	·194	·054	·132	·202	·059	·142	1,700	230	1,077	20·5	17·4	19·0
Chalk water delivered by the Kent Company.	41·74	38·52	39·79	·254	·088	·143	·003	·000	·001	·003	·000	·002	·496	·320	·365	·473	·321	·372	4,220	2,890	3,393	28·8	23·8	27·3
Loch Katrine water as delivered in Glasgow.	—	—	3·28	—	—	·256	—	—	·008	—	—	·002	—	—	·031	—	—	·041	—	—	0	—	—	·3
Water supplied to Manchester - -	—	—	6·8	—	—	·242	—	—	·026	—	—	·001	—	—	·001	—	—	·028	—	—	0	—	—	2·7
Water supplied to Lancaster - -	—	—	3·54	—	—	·157	—	—	·001	—	—	·001	—	—	·036	—	—	·038	—	—	50	—	—	·1
Water from the Welsh district - -	9·60	2·79	4·85	1·040	·200	·460	·013	·000	·006	·008	·000	·003	·068	·000	·017	·069	·002	·025	360	0	47	3·0	·4	1·4
Ditto, exclusive of flood samples -	9·60	2·79	4·95	·544	·200	·289	·010	·000	·004	·008	·000	·003	·068	·000	·022	·069	·002	·028	360	0	63	3·0	·4	1·5
Ditto, ditto, and of Bala Lake and feeders.	9·60	3·37	5·25	·544	·200	·293	·010	·000	·004	·008	·000	·003	·068	·004	·026	·069	·010	·031	360	0	76	3·0	·9	1·7
Water of Bala Lake - - -	—	—	2·79	—	—	·227	—	—	·001	—	—	·001	—	—	·000	—	—	·002	—	—	0	—	—	·4
Water from Cumberland and Westmoreland district.	13·60	2·14	4·74	1·059	·066	·276	·068	·000	·010	·006	·000	·002	045	·000	·009	·088	·003	021	140	0	6	8·0	·7	2·2
Ditto, exclusive of flood samples -	13·60	2·14	4·68	·536	·066	·211	·022	·000	·006	·004	·000	·002	·045	·000	·009	·048	·003	·017	140	0	6	8·0	·7	2·2
Ditto, ditto, and of Dacre Beck and Lower Lowther.	6·60	2·14	4·00	·536	·066	·205	·012	·000	·005	·004	·000	·002	·045	·000	·009	·048	·003	·016	140	0	7	2·9	·7	1·7
Water of Ullswater Lake - -	—	—	3·63	—	—	·067	—	—	·000	—	—	·003	—	—	·005	—	—	·007	—	—	0	—	—	1·9
Water of Thirlmere Lake - -	—	—	2·66	—	—	·194	—	—	·004	—	—	·003	—	—	·002	—	—	·008	—	—	0	—	—	·7
Water of Haweswater Lake - -	—	—	3·56	—	—	·158	—	—	·004	—	—	·004	—	—	·000	—	—	·007	—	—	0	—	—	1·3

* This high number occurred only once in a sample of water collected from the West Middlesex Company's mains. The impurity was abnormal, and was occasioned by the fracture of one of the mains and the consequent access of sewage to its contents, whilst the pressure was removed in accordance with the intermittent system of service.

The numbers in the above columns all refer to 100,000 parts of each water. The table is to be read thus:—100,000 lbs. of Thames water, as delivered by the five metropolitan companies drawing their supplies from that river, contained in the last six months a quantity of solid impurity amounting to 29·84 lbs. in the maximum, 23·70 lbs. in the minimum, or to 26·78 lbs. on the average. The organic matter constituting a portion of this impurity contained on the average ·275 lb. of carbon and ·011 lb. of nitrogen. This solid impurity also contained an average amount of ammonia equal to ·007 lb., and of nitrogen, in the form of nitrates and nitrites, ·192 lb.; whilst the total amount of *combined* nitrogen in every form averaged ·213 lb. The above quantity of water had been, after its descent to the earth as rain, contaminated with sewage or manure matter equivalent to 1,751 parts of average filtered London sewage. By gradual oxidation, partly in the pores of the soil, partly in the Thames or its tributaries, and partly in the reservoirs, filters, and conduits of the companies, this sewage or other similar contamination had been entirely converted into comparatively innocuous inorganic compounds before its delivery to consumers. Finally, 100,000 lbs. of Thames water contained on the average 19·3 lbs. of carbonate of lime, or an equivalent quantity of other soap-destroying ingredients.

The foregoing table permits the following conclusions to be drawn:—

1. The total solid impurity in the Welsh and Cumberland waters is very much less than that in the purest of the waters now delivered by the London companies. On the average of the whole number of samples it amounts to about one-fifth of that contained in the London waters; but if we may be permitted to assume that the water actually delivered from large storage reservoirs in the two districts would have a degree of purity equal to that now collected in the lakes, it would scarcely contain more than one-tenth of the solid impurity of the present London supply.

2. The amounts of organic carbon and organic nitrogen in the present and proposed supplies do not differ to such an extent as to compel a decided preference for either.

3. In the inorganic forms of combined nitrogen, viz.—ammonia, and especially nitrates and nitrites, both the proposed supplies exhibit great superiority over the waters at present delivered in London. The Welsh waters do not contain on the average more than about one-tenth, and the Cumberland waters only about $\frac{1}{10}$th, of the amount contained in the London water, whilst the lake waters of both districts are almost absolutely free from this form of impurity. The significance of such impurity has already been remarked upon, as bearing witness, when the contamination exceeds a certain proportion, of previous contact with decaying organic matters, generally of animal origin. This excess of mineral nitrogenous impurity, to which the name *previous sewage contamination* has been applied, exhibits in the most striking light the vast superiority of the proposed over the present water supply. In the whole of the Cumberland and Westmoreland district this contamination only occurs in one instance, viz., the Upper Kent, and that to a small extent only. In the Welsh samples there are only three instances, whilst not one of the lake waters of either district exhibits this contamination. On the other hand the waters at present supplied to London betray an average amount of this impurity, which would be produced by the oxidation of from 1 to more than 3 per cent. of their volume of average London sewage.

4. With two exceptions all the waters from the proposed sources of supply are of sufficient softness, their hardness averaging considerably less than $\frac{1}{10}$th of that of the softest at present supplied to London.

5. No apprehension of lead poisoning need be entertained from the use of the waters from either district in the ordinary lead service pipes of the metropolis.

6. The waters from the proposed sources compare favourably with those which have been substituted for the old supply in Glasgow, Manchester, and Lancaster.

E. Frankland, F.R.S.

P.S.—Substantially I agree with the preceding observations of my colleague Dr. Frankland in everything that relates to the character of the waters of Wales and Cumberland which we have examined. Taking them altogether, these waters are excellently suited for the supply of towns. They are of fair appearance, taste, and aëration. They contain but a small proportion of dissolved mineral matter, and are extremely soft, but unlike many soft waters, exert no sensible action upon ordinary lead. They contain moreover but small proportions of organic nitrogen and carbon (organic matter), and have not been at any time subjected to sewage contamination.

Although London is at present provided with an agreeable, and in my opinion perfectly wholesome water, still it is evident that for general town supply a soft water such as that of Wales or Cumberland is upon the whole more suitable than a somewhat hard water such as that of the Thames and Lea; and, further, that a water which neither contains nor has received sewage impurity is at any rate preferable to a water which certainly has received, even though it does not actually contain any such impurity.

I take this opportunity of acknowledging the advantage which our joint investigation has derived from my colleague's observations upon the subject of the action or non-action of soft water upon lead; and still more from his much desiderated invention of a trustworthy and delicate process for estimating the nitrogen of the organic matter of water.

William Odling, M.B., F.R.S.

APPENDIX E.

(REPRINT OF PAMPHLET.)

Metropolis Water Supply.

On the Supply of Water to London from the Sources of the River Severn.—By John Frederic Bateman, C.E., F.R.S., F.G.S., &c.

The extraordinary increase of London and other large towns in this country is one of the most remarkable circumstances of the age, and may well attract the serious consideration of all who are interested in the prosperity, the sanitary condition, and the well-being of large masses of human beings. London now contains, within the metropolitan district, a population of no less than 3,000,000 souls. It has trebled itself since the beginning of the century, doubled itself within the last 40 years, and is just half as large again as it was 20 years ago. Should it continue to progress at the same rate it will, in another 20 years, contain no less than 4,500,000 inhabitants, to which must be added the vast and still more rapidly increasing population of the surrounding suburban districts.

Amongst the many subjects of anxious consideration which are involved in the maintenance of so large and closely-concentrated a population, the question of their water supply is probably the most important, inasmuch as upon its quality and abundance, the health and comfort, and indeed the very existence of the population—as a town population—depend, and because it is absolutely impossible for individuals to help themselves in case of deficiency.

London is supplied by eight different water companies, who jointly pour into the metropolis and its immediate suburbs an average daily quantity of about 100,000,000 gallons of water, of which about one half are abstracted from the river Thames, and the other half from the original sources of the New River Company, from the river Lea, and from deep wells on the easterly and northerly sides of London, and from the river Ravensbourne on the south. Upon the present gross population the average supply is about 30 gallons per head per day. If the increase in the quantity supplied were only to keep pace with the increase in population, the daily supply 20 years hence would be about 150,000,000 gallons; but as the habits of modern life conduce to more liberal use of water, there can be little doubt that 160,000,000 or 180,000,000 gallons per day will then be too small a quantity for the wants of the population.

The rate of increase in the quantity consumed may be judged of by the facts that in 1850 the gross daily quantity delivered was 44,383,332 gallons; in 1856 it had reached "upwards of 81,000,000 gallons per day, having been nearly doubled in the short space of six years,"* and now, in 1865, it is about 108,000,000.

The water companies have up to this time fully met the demands upon them, and since the year 1852, when, in consequence of the then unsatisfactory state of the supply, they were compelled to go higher up the rivers and effect various other improvements, they have expended nearly 4,000,000*l.* sterling in extensions of works. In consequence of this outlay, notwithstanding the great increase in the

* *Vide* Report to Right Hon. William Cowper, by Messrs. Austin, Ranger, and Dickens, on Metropolis Water Supply, 21st July 1856.

number of their customers, the per-centage rate of their dividends has, with one or two exceptions, remained nearly unaltered, and in a pecuniary point of view, therefore, they are now little better off than they were previous to that time.

Short as the period is since the completion of the various improvements and alterations they were called upon to make, several of the companies are already looking anxiously for additional means of supply, and though those companies which are enabled to withdraw water from the Thames have still a considerable margin left, it will be insufficient to meet the wants of many years. By the various Acts which were passed in 1852, authorising the withdrawal of the water from this river, the maximum quantity which they were empowered to take was 100,000,000 gallons per day, and there are, I believe, many days in which between 60,000,000 and 70,000,000 gallons per day are abstracted, although the average daily abstraction, including Sundays, does not amount to 60,000,000. It is notorious also, that the volume of the Thames has been so diminished of late years, and has otherwise undergone such material changes, as to create great anxiety in the minds of those interested in the maintenance of the river. When the Acts of 1852 were passed it was estimated that the minimum quantity of water at Hampton was 362,000,000 gallons per day, and this minimum has been habitually considered, in round numbers, as 400,000,000. During the month of September in this year (1865), the river has been carefully measured above the waterworks at Hampton, and the gross daily quantity for a considerable period together has scarcely exceeded 300,000,000 gallons. The residents on the banks of the river below the lowest point at which water is taken by the water companies have this year been loud in their complaints of the diminution and pollution of the water, and have been holding public meetings for the purpose of seriously considering what steps are to be taken for maintaining the volume and purity of the stream.

There is no adequate source within the means of any of the existing companies to which they can resort. They will hardly be permitted to increase the draught from the Thames, and any supplies which could still be obtained from the chalk basin on which London lies are altogether insufficient to meet future demands. It is therefore matter of urgent necessity that the question should be broadly and liberally considered, while there is yet time to execute the requisite works for obtaining a full and ample supply from other distant sources, before those still at the command of the companies are exhausted.

What would be the effect of such a deficient supply of water as many of the towns in the kingdom have recently been labouring under, in a city containing above 3,000,000 people, it is fearful to contemplate, and no narrow considerations of parsimonious economy ought to be allowed to interfere with the execution of any large and comprehensive scheme which would ensure for very many years a full and abundant supply.

With the example of such judicious outlay, and such successful results as have attended a wise expenditure in this direction at Manchester and Glasgow, it can surely never be that London will hesitate in spending a like sum in proportion to its means, for obtaining a similar supply of water, if it can be shown that it is possible to obtain it.

But beyond the mere quantity of water, there are other considerations of equal importance. Purity is as essential to the well-being and sanitary condition of the town; and the quality of softness especially, is most important on the ground of economy in the use of the water. When the Loch Katrine water was introduced into Glasgow it was estimated, on the most careful computation, that the economy which resulted in domestic establishments was equal to the whole rate paid for the water supply, or 36,000*l.* a year upon a population of 400,000 persons; and this was by the substitution of water of about 1 degree of hardness as compared with the water of the Clyde, which varied from 7 to 9 degrees of hardness. The saving in trading establishments where water was used for delicate operations could not be fully estimated; but in the article of soap alone it saved five-eighths of all that had been previously used, and, probably, a like proportion in dye-drugs and chemicals.

Assuming these figures to be correct (and the facts were most carefully worked out at the time), the saving to the inhabitants of London, by substituting water of equal quality with Loch Katrine in lieu of the hard water of the sources from whence the supply is now derived, averaging from 12° to 16° of hardness by Dr. Clarke's scale, would not be less than 400,000*l.* per annum. Were the water no harder in quality than the Clyde, the saving would be, in proportion to the population, about 300,000*l.* per annum; but considering that the London water is twice as hard as the Clyde, the calculation of 400,000*l.* a year is certainly below the truth.

I will not dwell upon the importance of soft water in its bearing on the health of the inhabitants, although I believe it is well established that many diseases of a painful character are clearly traceable to the use of hard water, and which are entirely absent in communities who are in the habit of using the soft water of the millstone grit or primitive formations. This aspect of the subject, though worthy of the highest consideration, I leave to those better able to treat it.

The pollution of rivers flowing through agricultural and populous districts is attracting every year more and more the serious attention of the public and the Legislature, and is leading to energetic efforts for the purpose of preventing the contamination to which the rivers are subject, more especially since the adoption of the more complete sewerage and drainage of towns than heretofore existed.

The population within the basin of the river Thames above the points at which the water is withdrawn for the supply of London exceeds 1,000,000 persons, of which 600,000 or 700,000 are congregated in large towns and villages, the drainage of which is either now, or soon will be, poured into the river, unless means are taken for its prevention. It has been conclusively shown that a very small increase in the organic impurities of a river, attributable to animal or vegetable decomposition, renders the water unwholesome, and, notwithstanding the self-purifying quality which running water no doubt possesses, and the efforts which may be made to prevent contamination, the probable condition of our rivers before many years has over is no gratifying speculation.

The supplies to large towns ought to be sought for in those mountain districts where the largest amount of rainfalls, where there is little or no population, where manured lands scarcely exist, and where copious springs are constantly supplying the purest and softest water. It is from such districts that Glasgow and Manchester and most of the large towns in the north of England and Scotland are supplied, and the inestimable benefit which has been conferred on those communities by such supplies can hardly be over-estimated or even appreciated. Such sources, still unappropriated, exist in abundance, but they are distant from London; not too distant, however, to prevent their being economically acquired, although cost in this essential element of healthful existence ought to be matter of secondary consideration.

Large experience in this special branch of engineering for the last 30 years has made me acquainted with almost every available source of supply in the kingdom, and with all the conditions and circumstances which are essential to the successful carrying out of projects of this nature. Some years ago I had occasion to consider a project advocated by the General Board of Health upon the result of surveys by the Hon. Wm. Napier in the Bagshot sands and the greensands of Surrey; and I ascertained from such information as then existed, and from surveys which I personally made, that a moderate supply of very excellent water could be obtained from these districts. It would, however, be altogether insufficient as a complete supply to the City, as a whole and more intimate acquaintance with all the circumstances and difficulties of the country which a residence in it of several years has afforded, has convinced me that, in a succession of such dry years as we have just passed through, the springs would be less than was at the time anticipated, and I could not now recommend the adoption of the scheme which was then advocated.*

No scheme, in my opinion, is worthy of attention which would bring in less than 200,000,000 gallons of water per day, at an elevation which would supply nearly the whole of the metropolitan district by gravitation without pumping.

The nearest district from which this quantity of unexceptionable water can be obtained is that which, lying on the flanks of the mountain ranges of Cader Idris and Plynlimmon, in North Wales, forms the upper basin of the main tributaries of the river Severn. Here the direction of the mountain chains, the heights of their summits, the proximity to the sea, their geographical position, and physical peculiarities, entitle us to expect a very large fall of rain. They are so similar in their general characteristics to the Cumberland and Westmoreland mountains that we should be justified in assuming (in the absence of more precise data), the recorded fall of rain in that part of the country for that which might be expected on the upper drainage of the Severn. A summit ridge or line of watershed, of irregular height and direction, extending from north to south, is crossed and broken by several parallel ranges of mountains extending from south-west to north-east, the intervening valleys on the west side of this irregular summit being quite open to the westerly winds. The valleys on this side, walled in as they are by mountains rising at their peaks to 2,500 and 2,900 feet in height, and so raising their heads above the general level of the rain

* *Vide* Return to an Order of the House of Lords, dated 22nd June 1852, in which, however, a printer's error occurred, by adding a cypher to my estimate, and so making it 12,000,000*l.* instead of 1,200,000*l.*

louds, form, as it were, so many funnels, up which the louds are driven over the low passes at the summit line of ater-shed into the valleys on the east, where, sheltered from ie wind, they discharge the bulk of their watery contents.

Under almost precisely similar circumstances, in the Cumberland lake district, the heads of the valleys on the asterly side of the mountain passes receive an extraordinary amount of rain, amounting in some cases to 150 nches as the rainfall of an average year. The careful bservations of the late Dr. Miller in this district have eterminded not only this almost tropical fall of rain, but lso, in a more conclusive manner than had previously een shown, the gradual increase in the amount as you scend the mountains up to considerable heights. His bservations extended over many years, and have been nore or less corroborated by other meteorologists in those ounties. The observations on the fall of rain in the Welsh nountains are, unfortunately, of a less extensive character, nd have been continued for only a short period, but, as far s they afford the means of comparison, there is every reason o believe that the rain will be found to be as great as it as been ascertained to be in Cumberland. From these bservations we should be justified in assuming the fall of ain in the valleys and upon the hills, from which the Severn derives its supplies, at not less than 70 or 80 inches er annum, on an average of say three successive years of ninimum rainfall.

The rain in the highlands of Scotland on the west coast s probably as great in amount as that which obtains in North Wales and in Cumberland and Westmoreland; but hat which falls upon the drainage ground of Loch Katrine s diminished by the clouds having to pass over several anges of mountains, with deep intervening troughs, efore they reach the hills which surround the basin of his lake. Here, however, the average rain is 78 inches, nd the minimum fall of three successive dry years is 6 inches per annum.

The average annual rainfall on the Penine chain of ills, which forms the backbone of England, as it is ommonly called, separating Lancashire and Cheshire from Yorkshire and Derbyshire and the east and west waterheds of the country, is about 50 inches; the net produce, r that which flows off the ground in dry years, at the Manchester waterworks, which lie in the heart of this istrict being 33 inches per annum.

From all these observations, and from many others which night be brought to bear upon the subject, we should be uite justified in assuming 45 inches as the annual net roduce of two or three successive dry years upon the rainage ground from which I propose to collect water or the supply of London; but in order to be within perectly safe limits I base my calculations on 36 inches only, eing but 10 per cent. more than the observed results at he Manchester waterworks, and probably only half the ross amount of rain.

Having determined the available portion of the annual ainfall which we can safely depend upon, it is a matter of asy computation to determine the area of drainage ground rom which the supplies must be collected; the next imporant considerations being the possible duration of drought, nd the capacity of reservoirs to afford a continuous upply throughout the longest droughts that may occur.

In these mountain districts. where it seldom ceases aining for many days together, storage for 120 days' upply would be ample provision, but I have endeavoured o obtain reservoirs of capacity sufficient to last out 140 or 50 days, without taking into account the produce of the springs and streams during that period, but which would, nevertheless, amount to a considerable quantity.

Among the many districts which present themselves for consideration, two admirable ones have been selected, each apable of supplying, in addition to the natural volume of the streams in dry weather, something more than 100,000,000 gallons of water per day for London, after giving compensation in water to the streams on which reservoirs will have to be constructed, or from which water will be abstracted.

The arrangement for water compensation to the streams and to those interested in the water is proposed to be on the same principle as that on which nearly all such claims have been adjusted in all the great waterworks of the kingdom. By giving a certain definite proportion of the ascertained or assumed available fall of rain, varying in quantity according to the peculiar circumstances of the streams affected, but generally about one-third of the whole amount in the manufacturing districts, where the water is largely utilized, the dry-weather stream, or what may be called the useful working volume, is materially increased to the advantage of those interested, and the reservoirs are filled from the flood waters which run uselessly and often mischievously away, and which form by far the larger portion of the water flowing from a mountain district.

The districts selected are free from metalliferous veins and from other sources of contamination. They are situated on the Upper and Lower Silurian formations, which yield water as pure in quality as that of Loch Katrine, and which affords sites for magnificent reservoirs, which may be constructed with perfect safety and facility, and of sufficient capacity to economize the full annual rainfall I have assumed, and to last out droughts of from 140 to 150 days' duration, both for town supply and river compensation.

One of these districts of 66,000 acres in area is situated a little to the east of the range of mountains, of which Cader Idris and Aran Mowddy are the highest summits, respectively of 2,914 feet and 2,979 feet in height, and forms the drainage ground of the rivers Banw and Vyrnwy, which join the Severn about half-way betwixt Welshpool and Shrewsbury; the other district, of about equal area, is situated immediately to the east of Plynlimmon, 2,500 feet in height, and forms the drainage ground of the upper portion of the river Severn proper. The discharge pipes of the lowest reservoir in each of these districts will be placed at an elevation of about 450 feet above the level of trinity high-water mark.

The water will be conducted by separate aqueducts, of 19 miles and 21½ miles in length respectively, to a point of junction near Marten Mere, a little to the north-east of the town of Montgomery, from whence the joint volume of the water will be conducted by a common aqueduct, crossing the river Severn close to the town of Bridgnorth, and passing near to, or within a few miles of, Stourbridge, Bromsgrove, Henley-in-Arden, Warwick, Banbury, Buckingham, Aylesbury, Tring, Berkhampstead, and Watford, to the high land near Stanmore, where extensive service reservoirs must be constructed, which will be at an elevation of at least 250 feet above Trinity high-water mark. From these reservoirs the water will be delivered to the city at "high pressure" and under the "constant supply" system. The length of the common aqueduct will be 152 miles, and will be capable of conveying 220,000,000 gallons of water per day. The total distance from the lowest reservoir on the Vyrnwy will be 171 miles, and the total distance from the reservoirs on the Severn will be 173½ miles, to which must be added the length of piping from the service reservoirs to London, about 10 miles, making the total distance 183 miles. From the reservoirs to Bridgnorth the aqueduct will be carried through the successive ridges of mountain which it will encounter, principally by tunnelling, in the same manner as the aqueduct from Loch Katrine to Glasgow. At Bridgnorth it will have to cross the Severn by inverted syphon pipes; thence, through a comparatively open country partly by covered aqueduct or tunnel where it is necessary to preserve the water from contamination—partly by open aqueduct where the country is favourable for such construction, and partly by syphon pipes where it crosses the valleys of the rivers Stour, Avon, and other streams. It will avoid all the coal fields near which it passes on its route, and be carried to the north of the saliferous deposits of Droitwich.

The works will be exceedingly simple in their construction, presenting no difficulties of an engineering character. No embankment of a reservoir will be more than 80 feet in height, and they will be placed in situations either where hard impervious clay, or the solid rock of the Silurian formation, afford the means of making perfectly safe and water-tight reservoirs. One of these reservoirs on the river Vyrnwy will, by an embankment of 76 feet in height, form a lake of five miles in length, and will contain 1,089,000,000 cubic feet; another on the river Banw, by an embankment of 80 feet in height, will form a lake of four miles in length, and contain 940,000,000 cubic feet; and a third in the same district, by an embankment of similar height will contain 732,000,000 cubic feet. Amongst the reservoirs on the Severn will be one which, by an embankment of 75 feet in height, will contain 2,230,000,000 cubic feet—this single reservoir being 150 per cent. greater than the available water in Loch Katrine.

The surveys by which these facts were ascertained were made soon after the completion of the Glasgow waterworks, in the autumn of 1860 and in the spring and summer of 1862, and the probable cost of the works has been carefully estimated.

Each branch of the works, down to the junction of their respective aqueducts, will cost in round numbers 1,100,000*l.*; and the main aqueduct from thence to London, including service reservoirs equal to 10 days' supply of 200,000,0000 gallons per day, or 20 days' of half this quantity, will cost in round numbers 6,400,000*l.*—making a total of 8,600,000*l.* These estimates include the cost of connecting the service reservoirs with the main pipes of the existing waterworks and 14 per cent. for contingencies upon the whole estimated cost of works, land, and piping; but the piping provided across the valleys of the main aqueduct is only on a scale of 120,000,000 gallons per day, as it can be added to from time to time as the demand increases. So also it would be unnecessary to construct the reservoirs

on more than one branch of the works in the first instance, by which the outlay of 1,100,000*l.* might be postponed until it was required.

The quality of the water as taken from the streams in dry weather is under 2° of hardness, averaging in fact, according to the analyses of the late Dr. R. D. Thomson, F.R.S., 1·6° only, the average amount of organic impurity being 1·35 grs. per gallon. The water, when collected in reservoirs from floods, will no doubt be softer than this, for the water of Bala Lake, derived from precisely similar geological formation, is but 0°·8 of hardness, with organic impurity of 1·28 out of a total impurity of all kinds of 2·08. The Bala Lake water is nearly identical in quality with the Loch Katrine water, which, from the average of many analyses, contains 2 grs. of impurity to the gallon, of which the organic impurity is less than 1, and the hardness under 1°.

The amount of the estimate need not startle the public, for it is not more in proportion either to the quantity of water to be obtained, or the ability of the inhabitants to pay for it, than has been expended in Glasgow, Manchester, Liverpool, and many other towns, while it is far below the cost incurred by many towns which could be mentioned.

Taking, first, the population as a criterion. The Loch Katrine works cost the people of Glasgow, about 400,000 in number, about 900,000*l.* for an immediate supply of something more than 20,000,000 gallons per day, with provision in most respects for 50,000,000; the Manchester waterworks, for a supply (if the works were quite completed) of about 25,000,000 gallons a day to 600,000 persons, have or will cost 850,000*l.*; the Rivington works, for the supply of Liverpool, equal to only 12,000,000 gallons a day to a population of perhaps 500,000, have cost about 900,000*l.* Of these three great enterprises Glasgow is much the cheapest, as, by a further outlay of about 200,000*l.*, or a total of 1,100,000*l.*, it can secure a supply of 50,000,000 gallons per day.

These figures summarized show that the cost of new works for procuring additional supplies of water has been: in Liverpool about 75,000*l.* for each million gallons per day, in Manchester 34,000*l.* for a like quantity, in Glasgow about 45,000*l.* for their first instalment from Loch Katrine, and 22,000*l.* per million when their full quantity is obtained.

The cost to London, estimated in this way, though smaller than in Liverpool, would exceed that of Glasgow and Manchester, for it would be 71,000*l.* per million for the first instalment of 120,000,000 gallons, and 49,300*l.* per million when the full quantity was obtained; but, as compared with many other places, London would contrast more favourably.

The cost of new works, however, only forms a portion of the gross cost of the supply of any of these places. The price paid for the previously existing companies has in each case to be added; and including this, and looking merely to the population, Glasgow and Manchester have obtained their water cheaper than London could do by any scheme to be proposed. The gross cost, including the purchase of previously existing rights, in each of these places and in Liverpool, has been, or will be, as follows:—

	Gallons per Day.	Cost.	Per Million Gallons.
		£	£
In Liverpool, for . .	16,500,000	1,900,000	or 115,115
In Glasgow, including the supply from the Gorbals waterworks and first instalment from Loch Katrine	27,000,000	1,600,000	,, 59,260
Ditto, when full supply from Loch Katrine is obtained	53,500,000	1,800,000	,, 33,645
In Manchester . . .	25,000,000	1,500,000	,, 60,000

In Liverpool about one-third of the water supplied has still to be pumped from the old wells in the new red sandstone, the annual cost of which should be capitalized, and the amount added to the gross cost of the works, before it can be compared with Manchester or Glasgow. If this were done it would raise the cost of supplying water there to 1,990,000*l.*, or 120,606*l.* per million gallons per day.

In London the gross cost, after capitalizing the present dividends and interest of the existing companies, if they are to be purchased, viz., 450,000*l.* per annum, at 25 years' purchase, will be 19,850,000*l.* for the first instalment of 120,000,000 gallons per day (exclusive of any of the New River supplies which may still be retained), or 165,416*l.* per million; when the full quantity from North Wales is introduced, viz., 220,000,000 gallons per day, the total cost will be 22,100,000*l.*, or 100,454*l.* per million gallons per day.

It would not be fair, however, to consider population only as a test of ability to pay for water. A fairer criterion is the assessable value of the respective places; and in this view, if water is to be paid for according to the value of the property to be supplied, London stands on nearly equal terms with any of the places named.

The gross assessable value, both in Glasgow and Manchester, upon which compulsory rates can be levied is about 1,200,000*l.*, of which, in both cases, almost exactly half, or about 600,000*l.*, is due in respect of dwelling-houses. The gross assessable value of London within the metropolitan district is nearly 15,000,000*l.* per annum, of which at least 10,000,000*l.* must be on dwelling-houses, in respect of which alone rates for domestic supply would be levied. If, therefore, you look at the gross assessable value London could bear an expenditure twelve times as great as that incurred by Manchester and Glasgow, or, on the average cost to the two places, nearly 19,000,000*l.* sterling and if you measure it by the assessment on dwelling-houses, it could bear an expenditure about sixteen times that borne by the two enterprising cities of the North, or a gross outlay of about 25,000,000*l.* sterling.

Fortunately for the citizens of London, they need not be afraid of having to provide for such an outlay, if the system which has been adopted in Glasgow and Manchester, and which has been found to work in every way so advantageously for all parties, be adopted in London.

In each of these cities the waterworks are the property of the corporation, and, therefore, of the inhabitants themselves. Manchester has the power to levy within its municipal bounds two unlimited compulsory rates; one called the *public* rate, levied in consideration of the protection against fire which "constant supply" and "high pressure" necessarily confer, and in consideration also of the great advantage which all property is supposed to derive from a full supply of water; and the other a *domestic* rate in respect of the water supplied for domestic purposes. In Glasgow the corporation have the power of levying a public rate not exceeding 1*d.* in the pound, an unlimited domestic rate on the city north of the Clyde, and a rate of 1*s.* in the pound on dwellings in that part of the city which lies on the south of the Clyde. These rates in all cases, in both cities, are compulsory rates leviable upon all parties, whether they take water or not. They are, moreover, leviable upon the actual rental of the property, and not upon the mere assessable value, which is always below the rent. Outside the city boundaries, and within the city for trading purposes, both corporations stand in the position of ordinary trading companies, selling the water to those who will take it at certain limited rates for the supply of dwellings, and on terms to be agreed upon for the water taken for trade. These extraneous sources of income form a very considerable portion of the water rental of both the cities, no less an amount than 56,324*l.* having been received last year in Manchester, and 35,277*l.* in Glasgow being equal to 145 and 65 per cent. respectively on the gross revenue derived from the domestic and public water rates.

The rates actually levied within the compulsory area at present are—in Manchester, 9*d.* in the pound for the domestic, and 3*d.* for the public rate; and in Glasgow, 1*s.* for the domestic, and 1*d.* for the public rate. Shortly after the completion of the Loch Katrine works, when the full amount of interest on capital came to be paid, and before the expansion of the supply for trading purposes had had time to develope, the domestic rate in Glasgow rose to 1*s.* 4*d.* in the pound on the north side of the river, which in addition to the public rate, was cheerfully and thankfully paid. For some years the rates in Manchester were eased to the inhabitants by a moiety of the gas profits, which belonged to the township of Manchester, being applied in part payment of the interest on the cost and the annual expenses of the waterworks. During this period the domestic and public rates were respectively 6*d.* and 2*d.* in the pound. Now, however, and for several years past, no assistance has been derived from this source, and rates of 9*d.* and 3*d.* are, with the trade income, sufficient to meet all the expenses of the undertaking.

In Liverpool, where the corporation also have the power of levying compulsory rates, the domestic rate is unlimited but the public rate is restricted to 6*d.* in the pound upon all property. The full amount of this public rate is actually levied, being (where the supply is for domestic purposes) in addition to a present domestic rate of 4½*d.* in the pound. The extraneous income, from the sale of water for trade, shipping, &c., for the year ending December 31st, 1864, was 39,508*l.*

In these cases, as in all others where corporations have been permitted to take the supply of water into their own hands, they have been obliged to purchase previously existing water companies, whose property was valued and paid for upon a fair estimate of the profit they could legitimately make; this system of purchase being that almost universally adopted in all the various cases where, of late years, the waterworks of companies have passed into the hands of corporations.

Now London has but to follow the example of the places named (and they are not the only places which might be held up as examples, although, perhaps, Manchester and

lasgow are the two most prominent cases of success), id it can obtain its water quite as good in quality and ite as cheap in price.

It is fortunate that the experiment of uniting the whole etropolis into one district, for drainage and other purposes hich affect its material prosperity, has already been tried id found successful in the case of the Metropolitan Board ' Works; and it would be a simple and no doubt an fective arrangement to let that, or a similar Board, stand . the place of the corporation in other towns, and be rmed into a water commission or corporation for the anagement of the whole water supply of the metropolis, ith power to levy, as in Manchester, Glasgow, Liverpool, id other places, compulsory rates for the payment of the terest on the outlay and the necessary working expenses.

There can be little doubt but that upon the security of ompulsory rates leviable upon all the property in the etropolis, the various water companies would be willing sell their undertakings, on condition of receiving the same ividends which they have been in the habit of receiving, he board or corporation taking upon themselves all their lia- ilities, and the payment of the interest on money borrowed.

According to the annual returns made by the several ater companies to the town clerk of the City of London, he gross amount of water rents of all kinds now received y the seven largest companies which supply the metropolis 702,059*l.* per annum; their working expenses, of which very large portion consists of the cost of pumping water, re 275,547*l.*, leaving a balance for the payment of interest n money borrowed and dividends to the shareholders of 27,512*l.* A portion of this sum is made up of the rental eceived from houses, chief rents, and other property; and hen the pumping establishments can be dispensed with on he introduction of water from Wales, a large amount of ery valuable property would be set at liberty, and might e disposed of to great advantage. The eighth company, iz. the Kent waterworks, no doubt from oversight, has ever made the returns required by Act of Parliament, and ts receipts and expenditure cannot therefore be ascertained y reference to public documents.

By the concentration of management which would result rom the amalgamation of all the various companies into one reat undertaking, a considerable annual saving would be ffected, and the whole cost of filtering, and nearly the hole cost of pumping water, which are estimated to cost bout 75,000*l.* a year, would be saved. There would, even fter the completion of the projected scheme, be some high oints and distant places to which the water would have to e supplied by the aid of steam power and pumping, but he quantity thus to be supplied would be small in propor- ion to the great bulk required by the remainder of the metropolis, and would form no very serious addition to the annual expenses.

I referred in the beginning of this paper to the rapid increase in the population of London and its suburbs, and now it is necessary to refer to the no less rapid, and, indeed, astonishing increase in the value of property. In 1862 the assessable value of property within the metropolitan district was 12,514,053*l.* Upon a reassessment this year (1865) the annual value is 14,524,797*l.*, and taking the progress of the past as an indication of what may be fairly assumed as the progress of the future, the assessable value of property within the metropolitan district may be expected to be 20,000,000*l.* sterling by the time all the works could be completed for bringing in a supply from North Wales, a period which may be estimated at, perhaps, seven years from the present time. Not, however, to overrate the means from which the annual revenue must be derived, I will take it at 18,000,000*l.* only, and, in the absence of correct information, I will assume the value of dwellings at two-thirds of this sum, or 12,000,000*l.* per annum.

From the figures I have thus briefly introduced, and adopting the principle I have advocated of a compulsory rate upon all parties within the metropolitan district, it is easy to calculate how far the scheme I have proposed will work out in a financial point of view. Before, however, stating these results, I may urge one aspect of the subject which, if favourably viewed by those to whom it must be addressed, would lighten the burden to be borne by the community.

The question is to some extent an imperial one, and it would be no unreasonable thing if such assistance were solicited from Government as would enable the board to borrow their money at the lowest possible rate at which money could be afforded by the State. The metropolis is not merely the home of the citizens of London—it is the residence of the Crown and the Court, the seat of the Government, the centre of parliamentary legislation, and the place in which the great bulk of the legal business of the country is transacted. Annually, for a certain portion of the year, all the wealth and fashion of the kingdom congregate within its limits, and it is, indeed, in every relation of life and business, so identified with the interests and well-being of the whole kingdom, that the public generally might well be called upon to contribute to a measure of such importance, by permitting the State to lend money for the undertaking, for a limited period, at three per cent. interest per annum. Except, however, for the relief of those who are the constant residents of London, and who form the great bulk of its population—the smaller tradesmen and shopkeepers, and the working classes—it is hardly necessary to look for such assistance.

Assuming, for purposes of calculation, that the money to be borrowed may be obtained at four per cent. interest, and cannot be obtained at less, and that the companies will be satisfied with the payment of their present dividends, secured upon the compulsory rates, the annual sum required to meet all items of expenditure will be as follows:—

The total cost of the works on a scale, so far as the aqueduct is concerned, of 220,000,000 gallons per day, and reservoirs and pipes for the supply of 120,000,000 gallons, will be 7,460,000*l.* To this sum must be added the cost of surveys, parliamentary expenses, interest upon money during the construction of the work, the cost of superintendence, legal expenses, and such like, and these I estimate at 1,140,000*l.* by the time the works are completed, making a total of -	£8,600,000
The interest upon this, at four per cent., is	£344,000
Add cost of management and working expenses, say - - - -	150,000
Payment of dividends to existing companies, and interest on their borrowed money	450,000
Total annual expenditure	£944,000

To meet these charges there would be received—	
Probable annual value of surplus property of companies which may be disposed of	£50,000
Sales of water for trading purposes, and to suburban districts, and places on the line of aqueduct, probably - -	250,000
Compulsory rate for domestic supplies, at 10*d.* in the £, on 12,000,000*l.* - -	500,000
Compulsory public rate, at 2*d.* in the £, on 18,000,000*l.* - - - -	150,000
Total annual income	£950,000

The above is the worst view that can be taken of the financial position. Every succeeding year after the completion of the works the area of taxation and the means of raising revenue will be increased by the extension of the metropolis, while the annual expenses will remain nearly stationary, until the full quantity of water which the aqueduct will bring is exhausted. When this time approaches other contiguous mountain districts must be laid under contribution and a new aqueduct constructed. Twenty-five or 30 years will probably elapse before this occasion arises, even if none of the present supplies, such as those of the New River Company, which can be supplied by gravitation, are looked to as auxiliary means for meeting many public and trade demands where superior quality of water is not essential.

Possibly some of the items of probable revenue in the estimate I have made may be regarded with doubt, such as that to be derived from the sale of water for trade purposes and suburban districts. It is, however, considerably within the result obtained in Glasgow, in Manchester, and in Liverpool, and may, therefore, be fairly expected to be realized; but should it fall short of the sum estimated, and should the money have to be raised at four per cent. interest, as I have assumed, the compulsory rates must be correspondingly increased by perhaps 1*d.*, or at most 2*d.*, in the pound, when, even then, they would be below those which have been paid by Glasgow, and much below those paid in many other places. A reduction of one per cent. interest on the capital to be raised for new works would make an annual saving of 85,000*l.*, and if, by the aid or favour of Government, a further sum could be obtained at this amount of interest for the purchase of what would become water companies' annuities, at 25 years' purchase, there would be a further saving of 116,000*l.* per annum, making a gross annual saving of 201,000*l.*, being equal to a reduction of 4*d.* in the pound on the domestic rate. If this can be accomplished the metropolis will acquire not only an unlimited supply of water, delivered in the most perfect manner, and unsurpassed in purity and softness, but it will obtain it at no greater annual cost per head than is paid for a similar inestimable benefit in Glasgow and Manchester.

JOHN FREDERIC BATEMAN.

16, Great George Street, Westminster,
November 1865.

TABLES.

Table A.—Metropolis Water Supply.

Estimated cost of new supply from North Wales to carry out one branch of the scheme, either that for bringing wate from the river Severn or from the rivers Vyrnwy and Banw, and to construct the aqueduct from Marten Mere t London, capable of conveying 220,000,000 gallons per day:—

	£
Reservoirs and works on the rivers Vyrnwy and Banw, or on the upper sources of the Severn, and the construction of the aqueduct from the reservoirs to Marten Mere, capable of conveying 130,000,000 gallons per day, including land and contingencies	1,100,000
Main aqueduct from Marten Mere to London, capable of conveying 220,000,000 gallons per day, including land and contingencies, and including also the piping from the service reservoirs to London	5,860,000
Service reservoirs near London, including land and contingencies, and cost of connecting new piping with the existing systems	500,000
	7,460,000
Interest on outlay during construction of works, and general expenses, &c., &c.	1,140,000
Total cost for the first supply of 130,000,000 gallons per day	£8,600,000

Subsequent outlay for completing the whole scheme for 220,000,000 gallons per day:—

Cost of first 130,000,000 gallons per day	8,600,000
Reservoirs and works on the second branch of the scheme to Marten Mere	1,100,000
Additional syphons on main aqueduct between Marten Mere and London	550,000
Outlay for additional piping in the metropolitan district, service reservoirs, interest on outlay during construction of works, and general expenses	600,000
	£10,850,000

TABLE B.—General Particulars of the Drainage Areas, Estimated Supply of Water, and Reservoirs

DISTRICT.	Drainage Ground.	Assumed available Rain-fall per Ann.	Total Average Quantity per Day.	Assumed Compensation to Rivers, One-fourth.	Remains for City per Day.	Particulars of Reser		
						Height of Embank-ment.	Area of Surface of Reservoir.	C
	Acres.	Inches.	Gallons.	Gallons.	Gallons.	Feet.	Acres.	C
RIVERS VYRNWY AND BANW BRANCH OF THE SCHEME.								
River Vyrnwy.								
Llanwddyn Reservoir — The drainage to this river below the embankment of the Llanwddyn reservoir, amounting to 10,879 acres, is proposed to be diverted and impounded in the reservoir on the river Banw, at Rhyd-e-Gro, and is included in the drainage to that reservoir. The total drainage affected on the river Vyrnwy is therefore 33,231 acres.	22,352	—	—	—	—	76	1,000	1,08
River Banw.								
Reservoir at Can Office, which will receive, in addition to its own drainage, the surplus water from 12,507 acres on the Nant-e-Eira stream	15,044	—	—	—	—	80	800	94
Reservoir at Rhyd-e-Gro, which will receive the water from the drainage area of 10,879 acres on the river Vyrnwy, as above	16,477	—	—	—	—	80	600	73
Reservoir on Nant-e-Eira stream — surplus water to be diverted to reservoir at Can Office	12,507	—	—	—	—	80	200	26
Totals	66,380	36	148,541,508	37,135,376	111,406,130	—	2,600	3,02
RIVER SEVERN BRANCH OF THE SCHEME.								
River Clywedog.								
Part of the water from this area will be stored in the reservoir shown, and the surplus water diverted to the reservoir at Trefeglwys	13,500	36	—	—	—	70	200	21
River Dulas—consisting of the Cwm Bedan, Afon Tylwch, and other streams. The surplus water to be diverted to the reservoir at Trefeglwys — The reservoirs to be constructed on these streams have not been surveyed, but they are estimated at the same cost and capacity as that on the river Clywedog.	15,139	—	—	—	—	—	200?	217
River Carno.—The water to be wholly diverted and stored in the reservoir at Trefeglwys	17,289	—		—	—	—	—	
Rivers Tyrannon and Ceryst.								
Reservoir at Trefeglwys	18,264	—	—	—	—	76	1,600	2,230
Totals	64,192	36	1,640,407	35,910,102	107,730,305	—	2,000	2,665

After deducting compensation to the rivers affected, at the rate of one-fourth of the assumed rainfall, the reservoirs will afford a supply of the City—

	Gallons per Day.		Gallons per Day.	
From the rivers Vyrnwy and Banw branch of the scheme of	118,088,040	for 120 days; or of	101,218,660	for 140 days.
From the river Severn branch of the scheme of	104,135,625	„ „	89,259,107	„
Together	222,223,665		190,477,767	

These quantities are irrespective of the yield of the streams flowing into the reservoirs during the periods mentioned, the average volumes will be from 20,000,000 to 30,000,000 gallons per day.

ABLE C.—TABLE of the ANALYSES of WATERS collected from the Streams which are proposed to be abstracted for the Supply of the METROPOLIS from NORTH WALES, by the late Dr. ROBERT DUNDAS THOMSON, F.R.S.

—	Total Impurity.	Organic Impurity.	Total Hardness.
	Grains per Gallon.	Grains per Gallon.	Degrees.
iver Vyrnwy at Pont Hagel	2·60	·72	1·8
iver Banw at one mile below Can Office	2·84	1·16	1·8
iver Clywedog at Llanidloes Bridge	6·80	1·40	1·1
iver Severn and Afon Dulas at Llanidloes Bridge*	9·92	1·96	1·4
iver Severn at Caer Sws	7·24	1·44	2·2
COMPARATIVE ANALYSES OF OTHER WATERS:—			
och Katrine water, supply to Glasgow	2·35	·605	·8 in the Loch
anchester water supply	3·33	·680	1·5 as supplied in the City.
ala Lake	2·08	1·28	·8 in the Lake.

* In this sample was included water from the Hafron brook or river evern proper, which stream is excluded from the scheme in consequence of mineral workings at the head of the valley.

ABLE D.—TABLE showing the ANALYSES of the WATERS as supplied to the METROPOLIS by the WATER COMPANIES in April 1856, in May 1862, in November 1863, in September 1865.

—	Year.	Total Impurity.	Organic Impurity.	Total Hardness.	Permanent Hardness.*
		Grains per Gallon.	Grains per Gallon.	Degrees.	Degrees.
hames Water, as supplied by—Grand Junction Water Company	1856	22·59	1·38	14·37	7·92
	1862	19·00	1·84		
	1863	18·96	1·82		
	1865	17·15	·685	12·67	4·2
West Middlesex Water Company	1856	21·03	·96	14·28	8·12
	1862	18·16	1·60		
	1863	21·20	2·48		
	1865	16·62	·7	12·18	3·92
Chelsea Water Company	1856	22·79	1·42	13·80	8·63
	1862	17·25	1·40		
	1863	22·04	2·56		
	1865	17·11	·84	12·67	3·99
Southwark and Vauxhall Water Company	1856	21·19	1·37	13·59	8·22
	1862	19·28	2·20		
	1863	18·96	1·82		
	1865	17·81	·98	12·46	3·57
Lambeth Water Company	1856	19·84	1·33	11·98	7·82
	1862	20·28	2·20		
	1863	22·40	2·80		
	1865	17·75	1·01	13·16	3·5
Water from other sources, supplied by—New River Company	1856	21·78	·968	13·4	7·8
	1862	17·28	1·04		
	1863	21·88	2·52		
	1865	16·7	·455	12·46	2·87
East London Water Company	1856	22·05	1·09	13·98	7·53
	1862	19·20	1·76		
	1863	24·80	2·80		
	1865	17·99	·63	13·3	3·71
Kent Water Company	1856	26·10	1·37	12·03	10·1
	1862	24·60	2·80		
	1863	26·88	3·28		
	1865	27·72	1·61	17·71	5·53

* The permanent hardness in the analyses for 1856 is "after five minutes' boiling," that in the analyses for 1865 "after one hour's boiling."

The analyses for April 1856 are obtained from the report of Messrs. Hofmann and Blyth to the Hon. W. Cowper. The other analyses are obtained from the published returns of the Registrar-General; those for 1862 and 1863 being by the late Dr. R. D. Thomson, and those for 1865 by Dr. Frankland, F.R.S.

In reference to the analyses for the year 1865, in the preceding table, I have the following note from Dr. Frankland, dated Nov. 11th, 1865:—

"The composition of the waters supplied by the London companies is liable to considerable fluctuation, and you have selected a month peculiarly favourable for them. The results of analyses made here" (Royal College of Chemistry) "since February last, go to show that long-continued drought improves the quality of the waters, whilst rain has the opposite effect. Thus the dry spring and summer have, up to October, rendered these waters exceptionally good; and the results of analyses of waters collected this month (November), so far as they have been ascertained up to the present moment, show considerable higher numbers.

"In order that you may judge of this influence upon the quality of the waters, I append the proportions of solid contents and *volatile* or, as it is sometimes termed, *organic* impurity in the Lambeth Company's water from February to October of the present year" (1865).

LAMBETH COMPANY'S WATER.

1865.	Total solid Residue in 100,000 parts.	Volatile Matter in 100,000 parts.	Equivalent Results in Grains per Gallon, for comparison with the preceding Table.	
			Total Impurity.	Organic Impurity.
February	31·36	2·70	21·95	1·89
March	29·10	2·00	20·37	1·40
April	25·69	1·14	17·98	·798
May	27·60	1·95	19·32	1·36
June	25·34	1·55	17·74	1·08
July	23·15	·97	16·20	·68
August	25·18	1·12	17·63	·78
September	25·35	1·45	17·74	1·01
October	25·26	1·34	17·68	·94

TABLE E.—TABLE showing the AVERAGE RAINFALL in the CUMBERLAND and WESTMORELAND LAKE DISTRICT, from Observations made by the late Dr. MILLER, F.R.S., from 1844 to 1853.

Highest summits of the district, about 3,000 feet.
Lowest level, about 200 feet.

Place of Observation.	Elevation above the Sea.	No. of Years' Observations.	Mean Rainfall.
	Feet.	Years.	Inches.
Keswick	258	10	59·6
Loweswater	336	10	67·29
Crummock Lake	260	10	84·1
Gatesgarth	290	9	114·7
Eskdale Head	—	7	77·9
Wastdale Head	247	10	101·4
Selside	736	5	73·5
The Howe, Troutbeck	503	10	79·3
Ambleside	190	6	79·6
Seathwaite	—	9	140·5
Stonethwaite	340	7	111·4
Mean rainfall per annum of the district			89·93

TABLE showing RELATIVE RAINFALL at Places near the Sea, to the West of, and immediately adjacent to, the Mountains; and the RAINFALL in the LAKE DISTRICT generally, as above.

Place of Observation.	Elevation above the Sea.	No. of Years' Observations	Mean Rainfall.	Average Rainfall at places near the Sea.	Average Rainfall in the Mountain District adjacent.
	Feet.	Years.	Inches.	Inches.	Inches.
Whitehaven	90	10	43·5	46·75	89·93
The Flosh	—	10	50·0		

TABLE showing the RAINFALL in NORTH WALES, from SEA LEVEL to the MOUNTAIN DISTRICT adjacent, being the Returns for Six Months, ending August 1865.

PORT MADOC. Elevation, 20 feet above Sea.	MAEN-HOROG, CAEN-Y-COED. Elevation, 15 feet above Sea.	FESTINIOG. Elevation, 600 feet above Sea.	RHIWBRYFDIR. Elevation, 1,200 feet above Sea.
17·85 ins.	20·34 ins.	27·77 ins.	33·31 ins.

TABLE of the RAINFALL at two Places in each of the CUMBERLAND and WELSH DISTRICTS, showing the Relative fall of Rain at or near the Level of the Sea, and at Places nearer to the Mountains.

	CUMBERLAND LAKE DISTRICT.		WELSH DISTRICT.	
	Whitehaven.	Loweswater.	Port Madoc.	Festiniog.
Elevation above the sea	90 feet	336 feet	20 feet	60 feet
Rainfall	43·53 ins.	67·29 ins.	45·75 ins.	74·80 ins.

The rainfall of the Cumberland Lake district is the mean annual rainfall of 10 years.

In the Welsh district it is for 15 months, from May 1864 to August 1865 inclusive, omitting January 1865, for which month no return has been obtained. This return is worthy of notice, as being the record of a remarkably dry period.

The returns of the rainfall in Wales in the preceding tables are from the observations of Captain Mathew, of Wern, near Port Madoc.

TABLE F.—TABLE showing the AVERAGE RAINFALL in the LOCH KATRINE DISTRICT of the GLASGOW CORPORATION WATERWORKS.

Highest summit within area of drainage ground, Ben Venue, 2,800 feet. Lowest level about 300 feet.

Place of Observation.	Elevation above the Sea.	Number of Years' Observations.	Mean Rainfall.
VALLEY GAUGES—	Feet.	Years.	Inches.
Loch Venechar	275	4	64·7
Bridge of Turk	270	11	60·2
Glengyle	380	11	92·4
Loch Dhu	325	4	91·7
MOUNTAIN GAUGES—			
Loch Drunkie	420	4	71·3
Between Glen Finlas and Ben Ledi	1,800	10	59·9
Between Loch Chon and Loch Katrine	830	4	86·2
Between Loch Ard and Loch Katrine	1,500	10	84·8
On slope of Ben Lomond	1,800	11	91·9
Mean rainfall per annum of the district			78·12

TABLE showing the AVERAGE RAINFALL in the same District in a succession of THREE DRY YEARS.

Place of Observation.	Elevation above the Sea.	Annual Rainfall.			Average Rainfall.
		1855.	1856.	1857.	
	Feet.	Inches.	Inches.	Inches.	Inches.
Bridge of Turk	270	39·0	43·3	54·8	47·4
Between Glen Finlas and Ben Ledi	1,800	56·1	No return	48·3	52·2
Glengyle	380	65·5	79·3	91·6	78·8
Between Loch Ard and Loch Katrine	1,500	74·1	74·2	No return	74·1
On slope of Ben Lomond	1,800	69·9	81·0	85·5	78·8
Mean annual rainfall of three successive dry years					66·2

TABLE G.—TABLE of RAINFALL in the MANCHESTER WATERWORKS DISTRICT for the 10 years ending December 31st, 1864.

Highest summit within area of drainage ground, about 1,800 feet. Lowest level, about 500 feet.

Years.	MOTTRAM-EN-LONGDENDALE VALLEY.	
	Rhodes Wood Reservoir, 520 feet above sea level.	Woodhead Reservoir, 680 feet above sea level.
	Inches.	Inches.
1855	34·49	40·33
1856	49·16	50·89
1857	40·04	46·08
1858	42·77	45·54
1859	46·34	53·35
1860	47·85	53·69
1861	40·22	44·24
1862	47·28	49·63
1863	48·04	53·77
1864	38·50	43·52
Mean	43·469	48·104

Mean of the district, 45·786 inches.

These gauges are placed in the valley, on the west side o the summit ridge, and indicate a rainfall less than th average of the district.

RAINFALL at HOLME RESERVOIRS and at DUNFORD BRIDGE, on the Easterly Slopes of the Summit Ridg dividing this District from that of the Manchester Waterworks.

Place of Observation.	Elevation above the Sea.	Number of Years' Observations.	Mean Rainfall.
	Feet.	Years.	Inches.
Bilberry Reservoir	800	5	51·3
Holme Styes Reservoir	850	5	47·5
Dunford Bridge Railway Station	954	8	50·29
Mean rainfall per annum of the district			49·69

TABLE H.—LIVERPOOL CORPORATION WATERWORKS.

YIELD of the RIVINGTON DISTRICT, derived from information afforded by THOMAS DUNCAN, Esq., October, 1865.

Years.	Rainfall as per Daily Gauge.	Quantity delivered in Liverpool, run to waste, and Compensation Water—being total yield of District.		Equal to Proportion of Rainfall.		Quantity given as Compensation to Mills and Streams.		Left for Town, or run to waste.		Quantity actually to the Tow	
	Ins.	Gallons per Ann.	Galls. per Day.	Per Cent.	Inches.	Gallons per Ann.	Galls. per Day.	Gallons per Ann.	Galls. per Day.	Gallons per Ann.	Ga
1861	46·38	8,093,325,037	22,173,493	77·13	=35·77	3,029,500,000	8,300,000	5,063,825,037	13,873,493	3,797,393,993	1
1862	48·51	9,068,278,068	24,844,597	82·63	=40·08	3,029,500,000	8,300,000	6,038,778,068	16,544,597	3,938,501,428	1
1863	51·01	9,213,696,276	25,243,003	79·84	=40·72	3,029,500,000	8,300,000	6,184,196,276	16,943,003	4,060,640,184	1
1864	39·035	6,250,773,246	17,125.406	71·37	=27·85	3,029,500,000	8,300,000	3,221,273,246	8,825,406	4,031,913,758	1
Mean	46·233	8,156,768,157	22,346,624	77·74	=36·10	3,029,500,000	8,300,000	5,127,068,157	14,046,624	3,957,112,340	1

TABLE J.—STATEMENT showing the Annual Gross Revenue, Working Expenses, and the Dividends and Interest paid on the Capital and borrowed Money of the following seven Water Companies now supplying the Metropolis, viz.:—

The New River Water Company;
„ East London Water Company;
„ West Middlesex Water Company;
„ Southwark and Vauxhall Water Company;
„ Grand Junction Water Company;
„ Chelsea Water Company; and
„ Lambeth Water Company,

for the Eight Years ending September 30th, 1864, compiled from the Annual Returns of each Company made to the Town Clerk of the City of London:—

Years.	Gross Revenue.			Working Expenses.			Amount actually paid in Dividends, and Interest on Borrowed Money.		
	£	s.	d.	£	s.	d.	£	s.	d.
1857	527,007	16	4	224,756	10	1	308,801	16	2
1858	543,879	6	4	215,383	18	6	321,594	1	9
1859	582,699	12	0	228,985	16	2	337,813	3	4
1860	601,916	4	4	243,137	5	8	348,387	5	10
1861	616,604	16	6	254,721	9	5	358,379	8	4
1862	642,070	3	3	246,194	2	4	375,154	10	8
1863	670,117	7	11	256,841	5	4	392,635	8	1
1864	702,059	1	6	275,547	9	2	404,585	13	3

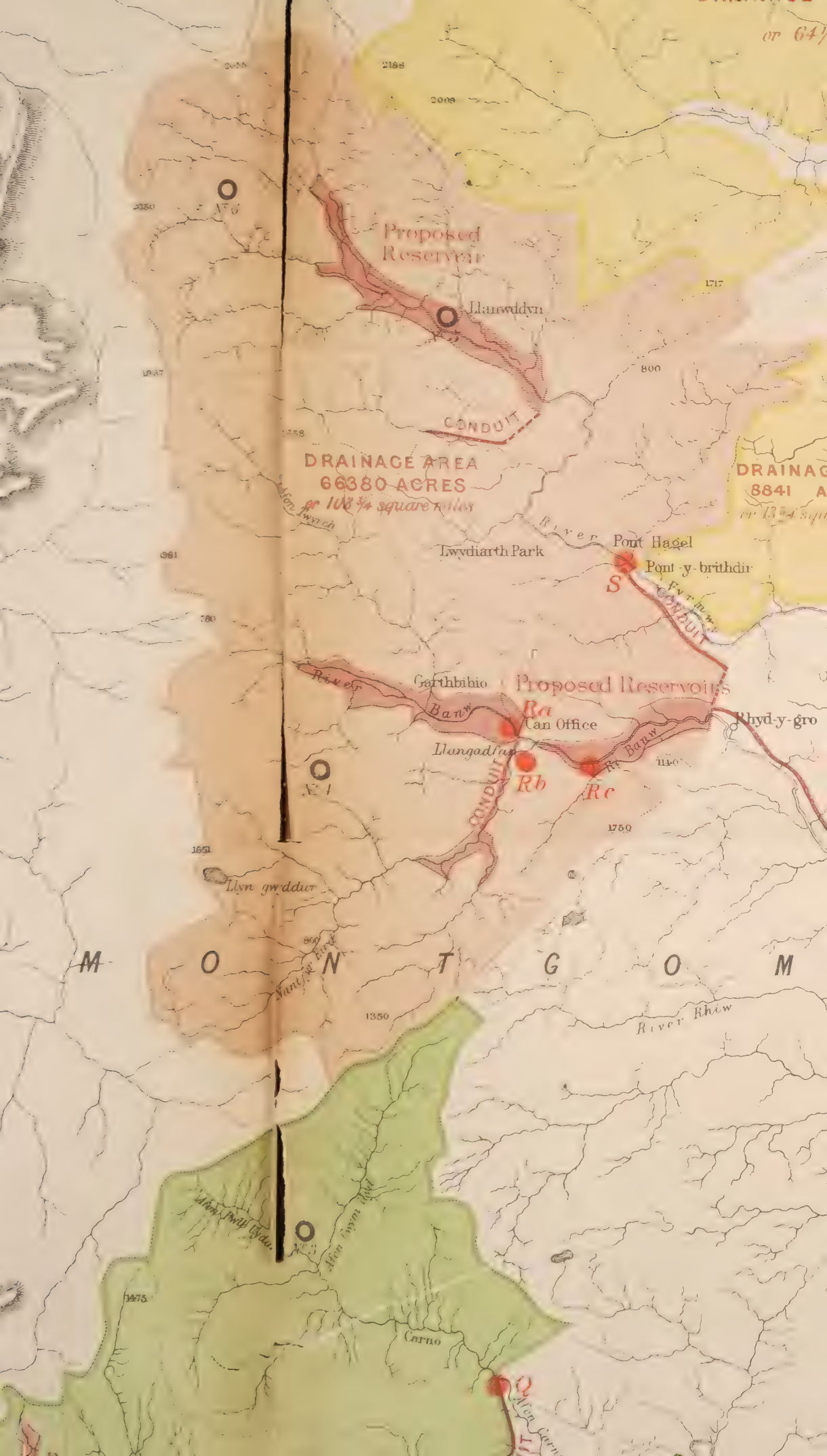
TABLE K.—TABLE of the entire WORKS of the METROPOLIS WATER SUPPLY, Approximate Estimate, 1865.

List of Metropolitan Water Companies.	Source of Supply.	No. of Houses supplied.	Gross Quantity per Day.	Aggregate nominal Steam Power.	Length of Mains and Branches	Area of Subsiding Reservoirs	Area of Filter Beds.	Area of Open Reservoirs for Filtered Water.	Area of Covered Reservoirs for Filtered Water.	Cost of Works as per former Return of 1850.	Cost of Alterations and new Works since 1852.
			Gallons.	Horses.	Miles.	Acres.	Acres.	Acres.	Acres.	£	£
River -	River Lea and Chalk Springs	130,000	30,000,000	2,000	630	66·00	9·00	None.	3·76	1,421,717	1,100,000
London -	River Lea -	85,000	19,000,000	1,450	460	50·00	12·00	None.	2·50	745,781	500,000
thwark Vauxhall	River Thames at Hampton	74,000	12,000,000	1,600	660	7·88	7·80	None.	None.	435,247	499,741
ibeth -	Ditto at Thames Ditton	51,000	11,000,000	900 +300 being erected	400	None.	0·73	2·00	4·50	307,352	450,000
st Middlesex	Ditto at Hampton -	37,000	9,500,000	1,100	300	25·00	8·00	None.	3·75	648,650	253,036
lsea -	Ditto at Seething Wells	33,000	9,000,000	800 +300 being erected	290	3·50	2·00	None.	2·50	455,712	550,000
nd Junction	Ditto at Hampton -	27,000	10,000,000	1,440	300	7·69	5·17	None.	1·07	522,295	322,557
Amalgamated: nt, Plumead, and Woolwich	Chalk Wells and River Ravensbourne -	33,000	8,000,000	900	250	2·65	1·55	1·00	None.	202,124	200,000
Totals - - -		470,000	108,500,000	10,790	3,290	162·7	46·25	3·00	18·08	4,738,878	3,875,334
als in corresponding Return ven in Messrs. Rouger, Austin Dixons' Report to Hon. W. owper in 1856.		328,561	81,025,482	7,254	2,086	141·46	40·59	2·80	14·90	4,738,878	2,282,824

BLE L.—COMPARATIVE STATEMENT of REVENUE derived at MANCHESTER, GLASGOW, and LIVERPOOL from the Public and Domestic Water Rates, and from Supplies of Water to Suburban Districts, and for Trading Purposes.

	Manchester, 1864–5.	Glasgow, 1863 and 1864.		Liverpool, 1864.
		1863.	1864.	
	Domestic Rate of 9*d.* in the £ on the Assessment of Dwellings, and Public Rate of 3*d.* in the £ on the Gross Assessment.	North Side of River Clyde. Domestic Rate of 1*s.* 4*d.* in the £ on the Annual Rent or Value, Public Rate of 1*d.* in the £. South Side of River Clyde. Domestic Rate of 1*s.* in the £, Public Rate of 1*d.* in the £.	North Side of River Clyde. Domestic Rate of 1*s.* 2*d.* in the £ on the Annual Rent or Value, Public Rate of 1*d.* in the £. South Side of River Clyde. Domestic Rate of 1*s.* in the £, Public Rate of 1*d.* in the £.	Domestic Rate of 4½*d.* in the £ on the Dwellings, and Public Rate (half paid by Tenants and half by Owners) of 6*d.* in the £ on the Gross Assessment.
	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*
mestic Rate - - -	22,707 18 4	50,652 18 2⅓	47,888 7 0	24,878 3 10
blic Rate - - -	15,955 3 1	6,507 3 4½	6,664 3 10	39,952 7 5½
Total - -	38,663 1 5	57,160 1 7	54,552 10 10	64,830 11 3½
venue derived from suburban supplies and from other than *domestic* supplies - - - - -	56,324 5 11	33,026 7 6½	35,277 13 8	39,507 14 9
r-centage amount on gross revenue derived from the domestic and public water rates - - -	145 per cent.	58 per cent.	65 per cent.	61 per cent.

WELLINGTON
MOSELEY WENLOCK
WOLVERHAMPTON
WALSALL
COAL FIELD
DUDLEY
BIRMINGHAM
STOURBRIDGE
KIDDERMINSTER
LUDLOW
STOURPORT
BROMSGROVE
LINE OF AQUEDUCT
River Teme
Tenbury
DROITWICH
HENLEY IN ARDEN
LEAMINGTON
WARWICK
SOUTHAM
Leominster
Malvern
WORCESTER
BROMYARD
STRATFORD upon Avon
River Severn
EVESHAM
Ledbury
CHIPPING CAMPDEN
SHIPSTON
TEWKESBURY
Winchcomb
MORETON in the Marsh
BEDDINGTON
CHELTENHAM
STOW
CHIPPING NORTON
GLOUCESTER
NORTHLEACH
BURFORD
WITNEY
CIRENCESTER
LECHLADE
ABINGDON
FARINGDON
CRICKLADE
HIGHWORTH
WANTAGE
LAMBOURN
BRISTOL
MARLBOROUGH
HUNGERFORD
NEWBURY


Proposed Reservoir
Llanwddyn
CONDUIT
DRAINAGE AREA
66380 ACRES
or 103¾ square miles
Afon Twrch
River
Pont Hagel
Pont-y-brithdir
Llwydiarth Park
Garthbibio
Proposed Reservoirs
Ra
Can Office
Rhyd-y-gro
Llangadfan
Rb
Rc
Bank
Llyn gwddur
MONTGOMERY
River Rhiw
Carno
Afon Carno
2188
2009
2050
1717
1937
1800
1458
1981
1780
1651
1140
1750
1350
1475

APPENDIX F.

(REPRINT OF PAMPHLET.)

On the FUTURE WATER SUPPLY of LONDON.—By GEORGE WILLOUGHBY HEMANS, C.E., and RICHARD HASSARD, C.E.

THE ideas on which the following project is based have been for a long time under consideration, and the descriptive particulars were actually preparing for circulation when the public were presented with the views on this subject of a very eminent gentleman, Mr. Bateman, C.E., in the form of a pamphlet, ably written and extensively circulated, and which has already attracted a large amount of remark and approval.

It is felt, therefore, that these suggestions appear now somewhat at a disadvantage, particularly as the sources of water supply recommended would seem at first sight to demand works, in length and extent, of greater and more startling magnitude than even the already sufficiently bold project of Mr. Bateman, for bringing water to London from the Welsh hills at a distance of 183 miles. The sources herein recommended lie at a distance of 240 miles from London, but, notwithstanding this increase of distance, we believe that when the subject is fully investigated it will appear that our project—although involving an apparently larger outlay in the first instance—will, from the absolute certainty of the rainfall, the extraordinary purity of the water, the facilities afforded by the existing lakes for the construction of the immense reservoirs, and from the revenue which may fairly be expected from the sale of water in the districts traversed by the aqueduct, be found the best and cheapest which has yet been proposed, and that ultimate economy will arise from its selection.

The future water supply of London, from its magnitude and importance, from the sanitary considerations involved in its successful elucidation, and having in view the enormous and rapidly increasing population which will afterwards be dependent upon it for one of the chief necessaries of life, is a question without parallel in the history of engineering, in ancient or modern times.

Of the existing water supply little need be said; that it is imperfect and unsatisfactory, both on account of quality of water, the intermittent nature of the supply, and rate of charge, is admitted on all hands; whilst, from the peculiar circumstances of the case, it is scarcely possible for the water companies to afford a supply much larger in quantity, or better in quality, than that at present furnished; they have done their best to carry out the obligations imposed on them by the Acts of 1852, and have expended large sums in their attempts to do so; the limit they can attain has, however, been nearly reached, and if the metropolis is to have a supply of pure water, such as is now enjoyed by many of the provincial cities and large manufacturing towns in the kingdom, it is full time that measures should be taken to investigate the question, and secure a suitable district from which to attain it, their being very few available localities now unappropriated, or which will not, owing to the growing necessities of this populous country, shortly be appropriated, for the supply of other towns and districts.

The population of London and its suburbs has increased of late years in such an extraordinary ratio—with the probability of at least this rate of increase being maintained—as to render it absolutely essential that any scheme now put forward should be designed so as to admit of a quantity of water, at least double the existing consumption, being brought to the metropolis, from time to time, as the requirements of the district demand additional supplies.

The population of the metropolis and suburbs may be taken at 3,000,000, and the quantity of water now actually supplied by the different companies at nearly 100,000,000 gallons daily.

Of this a very large proportion (about one-half) is extracted from the Thames, above tidal influence, as required by the Acts of 1852, and such a serious diminution of the volume of water in the river flowing onwards to London has of late attracted great public notice, to which it is not necessary at present further to advert.

The following extracts from the Registrar General's monthly reports, as published in the "Times," will show the qualities of the waters so obtained, as well as those of the waters of the other sources from which the metropolis is now supplied :—

"ANALYSIS of the METROPOLITAN WATER in December 1865, by Professor FRANKLAND, F.R.S., of the Royal College of Chemistry :—

Names of Water Companies.	Solid Matter in 100,000 parts of the Waters.	Organic and other Volatile Matter included in Col. 1.	Amount of Oxygen required for oxidation of Organic Matter.	Degrees of Hardness.*		
				Permanent.	Temporary.	Total.
Thames Water Companies.						
Chelsea - -	28·00	1·52	·1942	7·0	9·1	16·1
West Middlesex	28·91	1·49	·1045	6·8	11·9	18·7
Southwark and Vauxhall -	31·32	1·98	·1972	7·4	11·5	18·9
Grand Junction	29·51	1·91	·1722	7·4	11·0	18·4
Lambeth - -	29·06	1·08	·0842	8·8	7·6	16·4
Other Water Companies.						
Kent - -	37·45	0·61	·0070	8·8	17·4	26·2
New River -	30·02	0·54	·0396	7·0	14·1	21·1
East London -	33·90	1·56	·1274	7·2	15·0	22·2
South Essex -	38·10	0·86	·0112	5·8	19·0	24·8

"The table may be read thus :—100,000 lb. of the Chelsea water contained 28·00 lb. of solid matter, of which 15·2 lb. of organic and other matters were driven off by incineration. ·097 lb. of oxygen were required to destroy organic matter in the said quantity of Chelsea water. Of the solid matter, 16·1 lb. are carbonate of lime or its equivalent; of which 9·1 lb. are got rid of by boiling, and 7·0 lb. remain.

"With the exception of the water supplied by the Kent and South Essex Companies, the waters again exhibit this month a marked increase in the total amount of solid impurity as compared with last month; this applies also to the water supplied by the Lambeth Company, which was the only one which in October showed no increase of residue over the preceding month. On the other hand the organic and other volatile matter has (with the exception of the water supplied by the Grand Junction Company) decreased; while the amount of oxygen required for oxidation of the organic matter is in most cases less than in November.

"The waters of the Chelsea, Lambeth, Southwark, Grand Junction, and East London Companies were turbid when drawn from the companies' mains.

"The second column of this table contains the amount of solid matter left on evaporation and desiccation at 120 deg. C.—130 deg. C. (248 deg. F.—266 deg. F.)

"The results are recorded in 100,000 parts. By moving the decimal point one place to the right, the above figures express in milligrams the quantities contained in one kilogram of the several waters.

* The degree of hardness hitherto employed by chemists is that first proposed by Dr. T. Clark—viz., one grain of carbonate of lime, or its equivalent, in one imperial gallon of water, or one part in 70,000. The degrees of hardness used in the above table are readily converted into Clark's degrees by multiplying by 7, and then moving the decimal point one place to the left.

IN FEBRUARY 1866.

Names of Water Companies.	Number of Houses supplied in Jan. 1866.	Average Daily Supply of Water in Gallons during the Month of January 1866. (See note.)	Solid Matter in 100,000 parts of the Waters.	Organic and other Volatile Matter included in Col. 4.	Amount of Oxygen required for oxidation of Organic Matter.	Total Hardness.
Thames Water Companies.						
Chelsea - -	26,436	7,658,800	31·14	2·59	·0912	21·1
West Middlesex	35,486	7,657,423	30·40	2·00	·0739	19·8
Southwark and Vauxhall -	73,594	12,125,000	30·90	2·40	·0643	20·7
Grand Junction	25,308	8,067,112	31·40	1·60	·0555	22·2
Lambeth - -	35,420	7,620,200	31·16	1·65	·0592	21·0
Other Sources.						
Kent - -	32,412	5,376,676	37·92	1·80	·0104	27·4
New River -	111,864	22,330,000	29·50	1·68	·0576	22·0
East London -	88,340	17,592,000	32·78	1·68	·0636	23·1
South Essex -	750	161,000	40·60	1·36	·0086	26·5

"NOTE.—The quantities of water here given include the supply for manufactures and for various purposes other than domestic consumption. The table may be read thus:—The Chelsea Water Company supplied 26,430 houses, and an average daily quantity of 7,658,800 gallons in the month of January; 100,000 lb. of the Chelsea water in February contained 31·14 lb. of solid matter, of which 2·59 lb. of organic and other volatile matters were driven off by incineration. ·0912 lb. of oxygen was required to destroy organic matter in the said quantity of Chelsea water. 21·1 lb. are carbonate of lime or its equivalent. The fourth column of this table contains the amount of solid matter left on evaporation and desiccation at 120 deg. C.—130 C. (248 F.—266 F.) The results are recorded in 100,000 parts. By moving the decimal point one place to the right the above figures express in milligrams the quantity contained in one kilogram of the several waters.

"In comparison with the month of January the majority of the waters exhibit an increase in the total amount of solid impurity: the West Middlesex, New River, and East London Companies' waters form the only exceptions to this rule. The amount of organic and other volatile matter is also greater in all the waters, except those of the Grand Junction, Lambeth, East London, and South Essex Companies. Lastly, a larger quantity of oxygen is required for the oxidation of the organic matter than in the preceding month; the Chelsea, Grand Junction, South Essex, and Lambeth Companies' waters only being excepted.

"The waters of the Chelsea, Southwark, Lambeth, New River, and East London Companies were turbid when drawn from the Companies' mains."

The analysis for January was not published, but it will be evident from the remarks in that for February, that the water must have been of a quality similar to that of the preceding and following months.

It will be apparent also, from the above statements, that as regards six of the water companies, for some periods of the year at all events, private filtration would be necessary (it is in fact extensively practised) to ensure to the consumers a bright and potable water.

Taking for example the month of February, it would appear that out of a total daily average supply of 88,588,211 gallons no less than 67,326,000 gallons, or more than three-fourths of the whole, were delivered to the consumers in a turbid state.

The attributes of the future supply must be quantity, purity, and softness, with distribution at high pressure, on the constant system.

It would not be prudent, therefore, to provide for an eventual supply of less than 250,000,000 gallons daily, that is, 200,000,000 gallons for the metropolitan districts proper, and 50,000,000* gallons for sale to districts traversed by the aqueduct *in transitú* into London.

Experience has hitherto shown that the largest waterworks are in the end the cheapest, and those which furnish the largest quantity, and combine a supply for trading and manufacturing purposes with that for domestic and private consumption, invariably supply water at the lowest rate, to the ordinary consumer—that is, to the public at large.

This project is therefore put forward for the supply, not only of London, but where necessary, of the vast populat lying between the districts from which it is proposed obtain the water and the metropolis itself; and in th intermediate districts lie the populous and thriving tow of Lancashire, of the Potteries, and of the Midland Count

By such an arrangement it is obvious that the cost to parties will be materially lessened.

To obtain this necessarily great quantity of water, requisite purity and softness, we must seek a district considerable area, free from peat and contamination of ev kind, where the rainfall is large, and ascertained beyc doubt by a long series of observations, and where facilit exist for storing up the surplus waters of wet seasons, such altitudes as to permit of the supply being drawn and conveyed to London by gravitation, and of bei delivered there at about 220 feet above high water; usi in all cases where practicable the existing covered serv reservoirs, and failing these, covered service reservoirs to constructed in such localities as may be found on investig tion most advantageous for utilizing the present pipes a works of distribution.

This altitude of about 220 feet for distribution wou be most convenient and suitable for the entire of t metropolitan districts, would ensure an ample pressure ordinary domestic supply and in case of fire, and wou avoid the abandonment and destruction of the existi appliances of distribution, which would be entailed by t use of a much higher pressure, and by the adoption of different system of service; in fact the metropolis is large as to preclude its being dealt with otherwise than districts, excepting by the abandonment of a great porti of the present works and pipes, involving an obnoxious a undesirable expenditure.

There are, it is true, some elevated suburban districts f the service of which it would still be necessary to raise wat by pumping, but these could not, under any circumstance be included in a project for the supply of the metropolita districts by gravitation, and their area is comparatively small that it is scarcely necessary to notice them in the co sideration of this important subject.

Those well-known mountain ranges of the counties Westmoreland and Cumberland, draining into the river Lowther, Eamont, and Greta, and adjoining the lakes Haweswater, Ullswater, and Thirlmere, possess all th attributes of a locality from which an enormous amount the purest possible water may be obtained; and the existin lakes can easily and at small expense be adapted to for immense reservoirs for its conservancy and storage, at con venient altitudes for the water to be drawn off and conveye by gravitation to London.

By this process of conservancy the expense and incon venience of constructing such a number of wholly artificia reservoirs as would otherwise be necessary for the storag of the immense requisite quantity of water will be obviated

The area from which water is herein proposed to be col lected extends over 177 square miles, the altitudes varying from 500 to 3,200 feet above the sea. These, however, ar the extremes, the mean altitude will probably be 1,300 o 1,400 feet above the sea level.

The entire district is bare hill pasture and rock of th primitive formations, and excepting a small area in th vicinity of Ullswater, which can easily be excluded from th scheme, is free from mineral workings or other source of contamination, and the waters are of remarkable purity and softness, as the following analyses by and letter from Professor Way will show:

GRAINS PER IMPERIAL GALLON.

	River Lowther.	Haweswater Lake.	Ullswater Lake.	Thirlmere Lake.
Lime - - - - -	1·54	0·50	0·81	0·42
Magnesia - - - -	0·50	0·18	0·20	0·14
Soda - - - - -	0·80	0·71	0·51	0·46
Chlorides of Sodium & Potassium	0·48	0·40	0·69	0·77
Oxide of Iron, Silica, &c. -	0·50	0·25	0·20	0·05
Sulphuric Acid - - -	0·51	0·51	0·37	0·44
Carbonic Acid - - - -	2·05	0·82	1·03	0·56
Organic Matter - - -	0·62	0·62	0·35	0·77
Total Impurity - - -	7·00	3·99	4·16	3·61
Hardness before boiling - -	5·2°	2·0°	2·1°	1·5°
Hardness after boiling - -	4·4°	1·8°	2·1°	1·5°

* A small addition to the size and cost of the aqueduct would enable the provincial supply to be increased at any future time to 100,000,000 gallons daily.

These substances are probably combined as follows:—

GRAINS PER IMPERIAL GALLON.

	River Lowther.	Hawes-water Lake.	Ulls-water Lake.	Thirl-mere Lake.
Carbonate of Lime	2·75	0·90	1·45	0·75
Carbonate of Magnesia	1·05	0·36	0·42	0·29
Carbonate of Soda	0·70	0·56	0·40	0·20
Sulphate of Soda	0·90	0·90	0·65	0·78
Chlorides of Sodium & Potassium	0·48	0·40	0·62	0·77
Oxide of Iron, Silica, &c.	0·50	0·25	0·20	0·05
Organic Matter	0·62	0·62	0·35	0·77
Total Solid Matter	7·00	3·99	4·16	3·61

106, Leadenhall Street, E.C., March 21, 1866.

DEAR SIR,

I ENCLOSE the analyses of the waters of the river Lowther and of the three lakes, Haweswater, Ullswater, and Thirlmere.

As might have been expected, none of them shew more than a small proportion of solid matter per gallon; the river Lowther is the least praiseworthy on this account, though even that sample contains only 7 grains of total impurity per gallon.

The proportion of organic matter in all the samples is small; the water of the river Lowther is, however, slightly coloured, no doubt from peat.

The waters of the three lakes are as soft as any natural waters can be; the water of the river Lowther does not equal the others in this respect, but, as compared to the usual towns' supplies, would be considered a soft water.

On the whole, I have no hesitation in saying, that any one of these waters, or a mixture of them, would be admirably suited for the domestic supply of town populations, whether large or small.

I am, dear sir,

Yours truly,

G. W. Hemans, Esq., C.E. J. THOMAS WAY.

These results, although so favourable, exhibit the waters in their worst aspect and condition; the samples for anlaysis having been taken in January last, immediately after long continued and heavy rains, and include the drainage from the small mineral district, which is intended to be excluded from the scheme.

On the subject of the sufficiency of the rainfall no difference of opinion, happily, can arise.

The observations of the late Dr. Miller from 1847 to 1853 inclusive, as published in "Beardmore's Manual of Hydrology," give for the district and neighbourhood an average mean annual rainfall for that period of 100·56 inches, as will be apparent from the following table (No. 1).

It is a matter much to be regretted that the records of rainfall for this hill district, so carefully compiled up to 1853, should have been for the most part discontinued after Dr. Miller's death, as the years 1854 to 1859 inclusive were dry years, the mean annual rainfall of the 10 years 1850 to 1859, as given by Mr. G. J. Symons in his "British Rainfall" for 1863, as registered at the Seathwaite gauge, being 126·98 inches, as against 138·52 inches, the mean annual rainfall of the seven years ending 1853, and the mean annual rainfall at the Keswick gauge being 55·01 inches as against 60·82 inches for the same period of time, being in the first case ·92 and in the second ·90 per cent. of the mean annual rainfall of the seven years ending with 1853, which was a very dry year.

The years 1864 and 1865 were also dry years, the latter indeed, in the north-western counties, being one of extreme drought; the mean rainfall in the lake district for that year having been only 80·38 inches, or about 80 per cent. of the mean annual rainfall (100·56 inches) of the district for the seven years ending with 1853. (See Table No. 3.)

TABLE No. 1.

Name of Station.	Keswick.	Loweswater.	Crummock Lake.	Gatesgarth.	Eskdale Head.	Wastdale Head.	The How Troutbeck.	Ambleside.	Langdale Head.	Seathwaite.	Stonethwaite.	The Pike.	Great Gable.	Sprinkling Tarn.	Brant Rigg.	Seatoller Common.	The Stye.
Height above sea	ft. 258	ft. 336	ft. 260	ft. 290		ft. 247	ft. 503	ft. 190	ft. 250	ft. 368	ft. 340	ft. 3166	ft. 2925	ft. 1900	ft. 924	ft. 1338	ft. 948
Year 1847	ins. 58·23	ins. 66·30	ins. 82·32	ins. 106·20	ins. 74·90	ins. 96·30	ins. 78·00	ins. —	ins. 112·90	ins. 129·20	ins. 106·20	ins. —	ins. —	ins. —	ins. —	ins. —	ins. —
1848	66·40	76·67	98·07	133·50	86·80	115·30	91·30	77·60	130·40	160·90	130·20	94·70	91·30	148·60	109·20	139·50	—
1849	48·80	55·28	70·21	97·10	71·20	107·20	75·40	65·30	107·80	125·50	94·30	83·20	84·90	121·10	87·30	109·00	—
1850	59·53	68·80	85·66	108·80	81·70	108·80	79·80	79·80	126·60	144·00	105·80	80·30	87·30	127·80	91·10	138·80	174·30
1851	62·32	67·10	84·08	107·00	78·60	97·90	80·80	84·20	116·80	139·60	114·10	71·30	85·70	134·80	89·50	141·40	169·60
1852	79·97	80·53	103·40	134·90	88·80	100·60	115·40	104·30	134·10	156·70	133·90	81·30	81·20	125·30	98·20	156·60	167·70
1853	50·44	59·61	72·09	99·10	63·10	83·40	66·00	66·30	—	113·70	95·60	56·20	59·70	94·60	73·40	111·40	124·90
Total rain	425·74	474·29	595·83	786·60	545·10	718·50	586·70	477·50	728·60	969·60	780·10	467·00	490·10	752·20	548·70	796·70	636·50
Mean annual rainfall	60·82	67·75	85·12	112·37	77·87	102·64	83·82	79·58	121·43	138·52	111·44	77·83	81·68	125·37	91·45	132·78	159·12

Mean annual rainfall of the whole district for the above periods, 100·56 inches; and for the very dry year, 1853, 80·69 inches.

Table No. 2, also from Beardmore's Manual of Hydrology, giving the number of days' rain which actually fell during the seven years from 1847 to 1853 inclusive, at several of the Stations enumerated in the foregoing Table.

TABLE No. 2.

Name of Station.	Keswick.	Loweswater.	Crummock Lake.	Wastdale Head.	The How Troutbeck.	Ambleside.	Seathwaite.	Stonethwaite.
Height above sea	ft. 258	ft. 336	ft. 260	ft. 247	ft. 503	ft. 190	ft. 368	ft. 340
Year 1847	days. 204	days. 190	days. 199	days. 226	days. 188	days. —	days. 202	days. 196
1848	229	217	207	243	201	—	332	224
1849	205	191	185	236	186	159	193	183
1850	209	198	204	248	185	182	222	199
1851	211	202	206	232	195	178	219	206
1852	204	201	194	212	202	204	221	207
1853	172	189	183	203	173	149	217	191
Mean number of days' rain per year	205	198	197	228	190	174	229	201

Giving in the whole district a mean number of 202·75 days' rain in each of the foregoing years.

In addition to the foregoing information we have the following Table No. 3 of Rainfall for the six years 1860–65, as compiled by Mr. G. J. Symons, and published in the "British Rainfall:"—

TABLE No. 3.

Name of Station.	Scafell Pike.	Wastdale Head.	Brant Rigg.	Sprinkling Tarn.	Styehead Tarn.	The Stye.	Seathwaite.	Stonethwaite.	Keswick.	Lancrigg in Grasmere.	Ambleside.	Leskoth Howe.	Windermere Howe.	Ambleside Loughrigg.	Patterdale House.	Lowther Castle.	Eusemere Hill.
Height above the sea	ft. 3,200	ft. 247	ft. 695	ft. 1,985	ft. 1,472	ft. 1,077	ft. 422	ft. 330	ft. 270		ft. 150	ft. 200	ft. 470	ft. 57	ft. 500	ft. 840	f 5
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	in
Year 1860	—	—	—	—	—	—	142·20	—	54·17	104·87	—	79·97	102·58	—	—	45·33	-
1861	—	—	—	—	—	—	182·58	—	74·42	123·22	—	98·03	116·26	—	—	—	-
1862	—	—	—	—	—	—	170·03	—	61·37	—	—	88·26	94·27	—	—	—	-
1863	—	—	—	—	—	—	173·84	—	71·54	—	—	81·69	84·97	—	—	45·76	50
1864	73·20	86·78	7·21	119·52	108·73	—	134·67	100·76	52·68	—	74·40	74·09	75·74	74·63	61·49	35·08	-
1865	49·12	75·73	68·27	103·84	99·85	149·07	117·49	84·13	49·18	—	65·78	65·80	64·05	71·00	61·99	—	-

Mean rainfall of the district in the year 1864 = 81·99 inches.
Ditto - - - - - 1865 = 80·38 „

These last are rather lower than the true mean rainfall, owing to there not having been a gauge at the Stye in the year 1864, and owing to the Scafell gauge being rendered useless from snow during the greatest portion of the first three months of 1865.

In estimating for the supply of London and the intermediate towns the water producing capabilities of the district, we take it, to avoid question, at somewhat less than its minimum, viz., at 80 inches.

In a precipitous hill and rocky district, such as this, the loss from evaporation and absorption will be small, probably not more than 12 inches; we take it, however, at 14 inches, leaving 66 inches as the minimum depth of available rain during a continuous period of dry seasons.

This would be equivalent to a supply of 464,719,562 gallons daily throughout the year, and is a quantity much larger than required, or indeed than could be conveniently dealt with.

It is proposed therefore to limit the supply from this district to 250,000,000 gallons daily, and to give as compensation a quantity nearly equivalent to one-third of the abstracted rain, viz., 450,000 gallons daily for each square mile of drainage area.

By such an arrangement the floods now running to waste would be to a great extent controlled, and the dry weather yield of the district probably doubled in volume.

It will be evident that the district is capable of supplying a far larger quantity of water than that which it is proposed to take from it; in fact, the main cost of the project would be incurred, not in collecting and impounding the water, but in conveying it from its native district to the places of consumption.

The descriptive particulars of the project are as follows, and will best be understood by reference to the accompanying map:—

The districts from which water is proposed to be taken, with two small exceptions, lie on the northern slopes of the range of hills towering over Grasmere, Windermere, and Kendal, and draining into the rivers Lowther and Greta, and into the lakes of Haweswater, Ullswater, and Thirlmere.

On the eastern side of the collecting ground the works would commence on the river Lowther at Cooper's Green, in Sleddale, by an intercepting conduit, passing from thence round the hills to Swindale, where the first auxiliary reservoir would be constructed, and on to Haweswater, the surface of which would be raised 42 feet, or to 736 feet above the Ordnance datum.

From the north end of Haweswater another intercepting conduit would be constructed, passing round the eastern slopes of Bampton Common, and conveying to that lake the waters of the Hows Beck, Gill Beck, and Heltondale Beck streams.

A third conduit or watercourse would be constructed from the river Lowther, commencing at a point about 1½ miles below the village of Askham, passing round the hill to the west of Clifton, along the eastern slope of the valley of the river Eamont, and terminating at the north end of Ullswater, into which lake and into the river Eamont it would deliver at Pooley Bridge.

These three conduits would intercept all the waters of the river Lowther and its tributaries above Clifton, and conduct them into the Swindale auxiliary reservoir, and into the Haweswater and Ullswater lakes.

From the north-western end of Ullswater a conduit would be constructed to Dacre Bridge, which would intercept and conduct into it the waters of the Dacre Beck and its tributaries.

Thirlmere would be raised 64 feet, or to 597 feet above the Ordnance datum, and from its northern extremity conduits or catchwater drains would be constructed in easterly and westerly directions; the first named would pass round the northern slopes of Matterdale Common, and intercept the waters of the Mosedale Beck, Trout Beck, ar Barrow Beck streams, and complete a zone of interceptir conduit and watercourse between the northern extremiti of Ullswater and Thirlmere lakes.

The other conduit or catchwater drain would pass rour Bleaberry Fell, and along the edge of the table-land east Watendlath, and extending up to the Blea Tarn wou intercept all the upper waters of the Watendlath and Col barrow Fells.

By constructing a tunnel from the south end of Thir mere under Dunmail Raise Pass, and some short inte cepting conduits from its southern extremity, the waters about six square miles of a very wet district on the southe face of the hills may be conducted to and impounded that lake.

When Thirlmere is full, or the streams in flood, the wate may be passed into a reservoir to be constructed on S John's Beck immediately below that lake, where they wou be impounded, and given out as compensation to the mil owners on the river Greta at and above Keswick; whe both are full the surplus waters may be passed into Ull water, which with the auxiliary reservoirs to be constructe in Martindale would, in conjunction with Thirlmere, l used for towns' supply only.

The waters of the river Lowther, although of admirab quality, are the least desirable in the scale of excellence, ar it is proposed to use them mostly for compensation, passir them in the first instance down the river Lowther itself t a point 1½ miles below Askham, from whence they would l conveyed by a new channel to Pooley Bridge, and the delivered into the river Eamont.

The water supplied to London and the intervening towr would be taken almost entirely from Ullswater and Thir mere lakes, and would be of extraordinary purity an excellence, being under two degrees of hardness, and co taining per imperial gallon not more than about four grai of total impurity, of which scarcely more than half a grai would be organic matter.

Haweswater and Thirlmere are lonely and unfrequente lakes, occupying deep valleys, embosomed in mountain and afford admirable sites for the construction, at comp ratively trifling expense, of immense reservoirs, to whic additional supplies of water can with great facility l conducted.

The particulars of the reservoirs would be as follows:—

Name.	Area of collecting ground in square miles.	Area of Reservoir in acres.	Contents in Cubic Feet. For supply to Towns.	Contents in Cubic Feet. For Compensation.	Total Storage.
Swindale -	38	166		187,000,000	187,000,0
Haweswater -		683	235,200,000	961,100,000	1,196,300,0
Martindale -	95	255	336,000,000		336,000,0
Ullswater -		2,300	1,742,400,000		1,742,400,0
Thirlmere -	*	875	1,721,977,600		1,721,977,6
St. John's Beck Reservoir	44	360		380,000,000	380,000,0
	177	4,639	4,035,577,600	1,528,100,000	5,563,677,6

* If thought desirable, the waters from a further area of about eigh square miles draining into the Airy Beck and Dacre Beck, and no flowing into Ullswater, can easily be diverted and conveyed to Thirlmer

= to 120 days' supply at 250,000,000 gallons per day, and to 157 days' supply at 200,000,000 gallons per day—after giving credit for the average minimum summer yield, which will not be less than 40,000,000 gallons per day—and to 120 days' compensation at 450,000 gallons per square mile of drainage area; this will more than suffice in a district of such constant rain.

There would not be any necessity, in the first instance, for constructing the auxiliary reservoirs in Swindale and Martindale, as until the towns' supply exceeded 200,000,000 gallons per day Thirlmere and Ullswater would contain sufficient storage, and would be able, after giving credit for the summer yield, to work up to 135 days' supply, whilst compensation water would be given out from Haweswater and from St. John's Beck reservoirs; when the demand exceeds 200,000,000 gallons per day these auxiliary reservoirs may be constructed, and, if necessary, others in addition, as many sites are available; should the demand eventually exceed 250,000,000 gallons per day, a further area of 53 square miles of collecting ground may be obtained on the southern slopes of the range of hills above Ambleside and Kendal, by constructing reservoirs in the valleys traversed by the Troutbeck, the Kent, the Sprint, and the Bannisdale Beck streams, and an additional quantity of about 75,000,000 or 80,000,000 gallons daily may easily be obtained from these sources of supply.

As to the capability of the district no doubt therefore can exist, and it is worth consideration whether it might not be the wisest course in the first instance to construct those portions of the aqueduct which cannot be added to from time to time of sufficient capacity for this extended supply.

The surface of Ullswater lake would be ordinarily maintained at or about its winter level, and water drawn off from it for towns' supply at a depth of 20 feet, that is, at about 460 feet above the Ordnance datum; the shores, however, are mostly of a steep and precipitous nature, and any injury to the scenery or aspect of the lake would be more of a fancied than real nature.

Of course it would be impossible to carry out a scheme of this magnitude without doing some injury, but in the construction of these great reservoirs it would be reduced to a minimum; for instance, for Haweswater and Thirlmere, the total area of additional land required would not be more than about 750 acres, and there would be no residential damage. The number of houses which would be affected would not exceed 17 or 18, all of which, excepting three or four, are of the most ordinary class; and they can all, if necessary, be re-erected round the extended margin of the lakes.

At Ullswater the injury done, if any, would be very trivial. As long as the demand from the district did not exceed 200,000,000 gallons per day it would not be necessary to lower Ullswater at all until after a period of 67 days of absolute drought, Thirlmere being able to keep up the supply for that period of time; it would then take about 30 days more to lower Ullswater 8 feet, which would not be very much below its summer level; so that under these circumstances 97 days of continuous and absolute drought must occur before Ullswater would be sensibly affected.

When the demand has increased to 250,000,000 gallons daily, and the auxiliary reservoirs have been constructed, with their aid the towns' supply could be kept up from Thirlmere for a period of 70 days, and it would then take 23 days more to reduce Ullswater 8 feet, so that in this case 93 days of continuous and absolute drought would be necessary before the lake was reduced much below its summer level; and there is no record of drought of any such duration ever having occurred in this notoriously wet locality.

On this subject we are indebted to Mr. Samuel Marshall, of Kendal, who has been a careful observer of rainfall there since 1822, for the following valuable information:—

"The longest period of drought in this locality (Kendal), during the last 44 years, occurred in the spring of 1852, which, singularly enough, was also here the wettest year during that period.

"From the 19th February to the 29th April there were but three days on which rain fell, and the aggregate fall was only 0·21 inches, being a period of 70 days with less than a quarter of an inch of rain.

"The droughts next approaching this in duration occurred as follows:—

"In 1861, from the 1st April to the 8th June — a period of 69 days—there were but nine days on which rain fell, with an aggregate fall of 1·65 inches.

"In 1839, from the 28th March to the 4th June—a period of 67 days—there were but 12 days on which rain fell, with an aggregate fall of 1·97 inches.

"In 1826, from the 28th April to the 28th June—a period of 60 days—there were but eight days on which rain fell, with an aggregate fall of 1·12 inches.

"In 1829, from the 14th December to the 8th February 1830—a period of 55 days—there were but five days on which rain fell, with an aggregate fall of 0·65 inches.

"The years 1844, 1853, 1864, and 1865 were also dry years, but with droughts of much shorter duration than those above mentioned."

It must be borne in mind also that Mr. Marshall's observations relate to the rainfall at Kendal, which in many cases is not more than one-half of that in the mountainous districts above, where there is often a considerable amount of rain, whilst it is fine weather in the low country adjoining.

The water from Thirlmere would be drawn off at its northern extremity, and conveyed to Ullswater by conduit and tunnel; the tunnel would be eight miles in length, but shafts can be put down over the entire distance, and in such a case it is obvious there would be no greater difficulty in constructing a long tunnel than a short one; it is simply a question of greater length and of additional shafts.

From Ullswater the supply would be drawn off from the south end of the lake at Patterdale, and from thence carried by tunnel under Kirkstone Pass.

This tunnel would be the only work of unusual magnitude connected with the project; it would be 7¼ miles in length, but of this 5¼ miles would be ordinary and rather shallow tunnel, and would therefore present no difficulty; the central portion immediately under Kirkstone Pass would be 1¾ miles in length between the shafts, and would, at the rate of progress which has been effected at the Mont Cenis tunnel, occupy in its construction about three years after the shafts were sunk.

No doubt, with the rock-boring machines of the present day, it might easily be completed in that or a less period of time.

From the south end of the tunnel the water would be conveyed to London by conduit, tunnel, and iron pipes; the aqueduct would pass by Ambleside and Kendal, and down the eastern side of Lancashire, avoiding the Wigan coal-field, to the east of Manchester and of the Potteries district, and to the east of the Staffordshire coal-field and of Birmingham, and onwards towards London, following a route nearly parallel with that of the London and North-western Railway, and would terminate in a large regulating reservoir to be constructed to the north of Harrow, at a distance of about 12 miles from Cumberland Gate, Hyde Park.

The project may in fact be briefly described as an aqueduct, or arterial conduit, deriving its supply from the great rainfall and natural reservoirs of the lake country, passing through the heart of England, and capable of affording *in transitú* a practically unlimited quantity of the purest possible water to the vast manufacturing districts and population on the line of its route, as well as to the metropolis itself.

Some portions of the project and of the aqueduct may be carried out in detail, as the demand for water increases from time to time.

We now come to the consideration of the financial part of the scheme.

Of late years it has been pretty well recognized that all great projects of this and similar natures should be the property of the communities to whose necessities they minister, or in other words, that the consumers should be the proprietors of their own works, and guardians of their own interests.

It is also now equally recognized that the rates for water supply and drainage should be compulsory, and extend to all property within the area benefited. In different localities the rates are differently apportioned, but the principle is almost universally practised, and has been adopted in many large provincial cities and towns with great public advantage; it should, we conceive, *à fortiori*, be extended to the metropolis, and the water supply placed under the control of the Metropolitan Board of Works, or of a similar board, to be elected for the purpose, from the ratepayers themselves.

In this case it would of course be necessary to purchase the existing waterworks and incorporate them with the new project, securing to the different companies the net incomes they at present enjoy.

We learn from the pamphlet recently published by Mr. Bateman, C.E., on the water supply of London, that these in the aggregate amount to rather more than 400,000*l.* per annum, whilst their gross receipts are about 700,000*l.*, or nearly 1*s.* in the pound, on the present rateable value of the property in the metropolis, which amounts to about 15,000,000*l.* annually, and this would no doubt reach to a much larger amount by the time these proposed works were completed. We shall call it then 16,000,000*l.*, although, judging from the late ratio of increase, this would evidently be below the mark.

The cost of the project complete for a daily supply of 250,000,000 gallons, we estimate at 12,200,000*l.*

As, however, there would be no necessity for bringing the whole of this large quantity of water before the demand for it had actually arisen, we shall assume that 200,000,000 gallons only are brought in the first instance; that is—

	Gallons.
For domestic consumption - - -	120,000,000
For public and trading purposes - -	30,000,000
For sale to population on line of conduit	50,000,000
Total -	200,000,000

The cost of which would be—

Conduits, reservoirs, and works of collection - - - - - - -	£675,000
Tunnel from Ullswater to Ambleside -	350,000
Aqueduct to London - - - -	8,125,000
Regulating reservoir, &c., near London	500,000
	£9,650,000
Interest on unproductive capital during an average period of three years, and other expenses - - - - -	1,550,000
	£11,200,000

The annual expenses would probably be—

Interest on 11,200,000*l.* at four per cent. -	£448,000
Collection, management, and casual repairs	100,000
Present dividends to water companies -	425,000
	£973,000

To meet this we should have, after the works have been for some few years fairly in operation, a probable income of—

From the sale of 50,000,000 gallons daily, to towns, &c., on the line of aqueduct, at 3*d.* per 1,000 gallons -	£228,125
From the sale of 30,000,000 gallons daily in London, for public and trading purposes, at 3*d.** per 1,000 gallons - - - - -	136,875
From an average rate of 10*d.* in the pound on a property of 16,000,000*l.* -	666,666
	£1,031,666

which is 58,666*l.* in excess of what is required, as shown above.

In the estimate of income no credit is taken for the annual value of the assets and property of the water companies, which it would not be necessary to retain after the introduction of the new water supply.

This average rate of 10*d.* in the pound may be levied as may be deemed most equitable, say a 9*d.* rate for domestic consumption on an assumed house property of 12,000,000*l.* and a public rate of 3*d.* on a total property of 16,000,000*l.*, this would amount—

For the domestic rate, to - -	£450,000
For the public rate, to - - -	200,000
Total - -	£650,000

which would probably suffice.

It is not, however, to be expected that the 50,000,000 gallons daily proposed to be sold to the towns and populations on the line of the aqueduct could be disposed of all at once, and in estimating the rates likely to be levied on the citizens of London we must take that into account, and we shall now consider the question as if no water were disposed of.

This would leave a sum of 973,000*l.*—136,875*l.*=836,1 to be levied on the metropolis, and would amount to average rate of rather more than 12½*d.*, say 1*s.* 1*d.* in pound on all property; this would be the maximum r which under the most unpropitious circumstances it wo be necessary to levy and which would not amount to m than the actual rate now levied on property in the met polis by the existing water companies.

It is more than probable, however, that by the time th works were completed the rateable value of the metropoli districts would amount to 18,000,000*l.*, of which probal three-fourths, or 13,500,000*l.*, would be house property, a in this case, if no water were sold on the line of aquedu the rate necessary to be levied would amount to about 11 in the pound.

If the rateable value amounted to 18,000,000*l.*, a 25,000,000 gallons were sold daily on the line of the aqu duct, the necessary metropolitan rate would amount nearly 9¾*d.*, say 10*d.* in the pound.

If, however, the sale of water on the line of aqueduct h increased to 50,000,000 gallons daily, and the rateable val of the metropolitan districts had increased to 20,000,000 —events by no means improbable—the average necessa rate would not then amount to more than about 7½*d.*, s 8*d.* in the pound, and this would gradually be diminishe as the rateable value of the metropolitan districts, cause by suburban extensions, and the springing up of a new ar better class of property in the metropolis itself, progressed and to meet the future demands likely to arise from the and other causes, there would remain a further quantity 50,000,000 gallons daily, to be supplied at an outlay 1,000,000*l.*, which may be expended when the necessit arises.

On the subject of diminution of disease, of poors' rate of fire insurance, and of taxation generally, consequent o the introduction of a plentiful supply of pure water, no re marks are necessary: such results are too well known t require comment.

We trust we have shown, that not only is London withi the pale of an admirable supply, but that water of extra ordinary purity and excellence may be readily procured an distributed to its inhabitants at rates of charge at leas equally moderate with those at which other large towns ar supplied, and under no circumstances exceeding the rates levied for the present intermittent and unsatisfactory supply

In the autumn of last year, when the plans and general features of this scheme were nearly matured, a letter from Mr. G. J. Symons, the well-known meteorologist, appeared in one of the public journals; in it was mentioned the feasibility of procuring water from the Westmoreland and Cumberland hills for some districts in Lancashire, at that time suffering from drought, and since then the subject appears to have been taken up by Mr. Dale, C.E., of the Hull Corporation Waterworks; some particulars of a project for the purpose, put forward by that gentleman, having appeared from time to time in the scientific journal known as "Engineering."

Mr. Dale's project, as far as we can gather, is to supply a number of towns in Lancashire and Yorkshire from Haweswater and Ullswater lakes; but, excepting in the circumstance of these lakes being included in our scheme and forming a portion of it, there is no similarity or affinity between the respective projects.

G. Willoughby Hemans.
Richard Hassard.

1, Westminster Chambers,
July 1866.

* Only about one-half the price usually charged.

The Red & Blue circles are referred to in Mr Pole's Report on the selection of samples of Water. May 1867.

The Red circles shew the places where the samples were taken.

The Blue circles shew the sites of lead workings.

The block figures thus **165** *show the mean annual fall of rain in inches at the places marked further particulars are given in Mr Symons evidence*

AREA 95 SQUARE MILES

MARTINDALE COMMON

Auxiliary Reservoirs

AREA 38 SQUARE MILES

HAWES WATER

Swindale Auxiliary Reservoir

Ullswater

Haweswater Reservoir

Matterdale Common 50

Watermillock 55

Gowbarrow 72

Ullsteads 52

Swarth Fell 53

Pooley Bridge

Eusemere 43

Askham

Lowther Castle 44

Great Strickland 39

Tirril 39

Clifton

Shap

Patterdale 500

Measand Becks 52

Swindale Common

Mardale Green 108

Wet Steddale 113

Steddale

Coopers Green

Sleddy End 87

Fd 93

Fc 75

Fe

Ff

Fb

Ac 81

Wythburn 90

Aa

Bf 86

Geusmere 196

Ca

Cb

D

E

G

Bc

Bd

TUNNEL

CONDUIT

LINE OF WATERSHED

Barrow Beck

Dacre Beck

Matterdale Beck

Trout Beck

River Eamont

River Lowther

Hellondale Beck

Gill Beck

Hews Beck

Hawes Beck

Swindale Beck

Bampsgill Beck

Goldrill Beck

Red Crags 2328

Raven How 2358

Kidsty Pike 2560

High Street 2663

St Patrens Edge 2077

Kirkstone Pass

Red Tarn

Grisedale Tarn

Hayes Water

Brothers Water

Blea Water

Helvellyn 3118

Great Dodd 2804

Cockup 2756

Hart Crag 2698

Fairfield 2863

Dove Crag 2603

Hart Side 2698

Caudale Moor 2502

Red Screes 2541

Ill Bell 2476

Froswick 2359

Thornthwaite Beck 2155

Rydal Water

Grasmere Lake

Kentmere Reservoir

Wet Side Edge 2292

Yoke 2316

Ill Bell 2476

Froswick 2359

Thornthwaite Beck 2155

Rydal Water

Grasmere Lake

Kentmere Reservoir

Wet Side Edge 2292

Yoke 2316

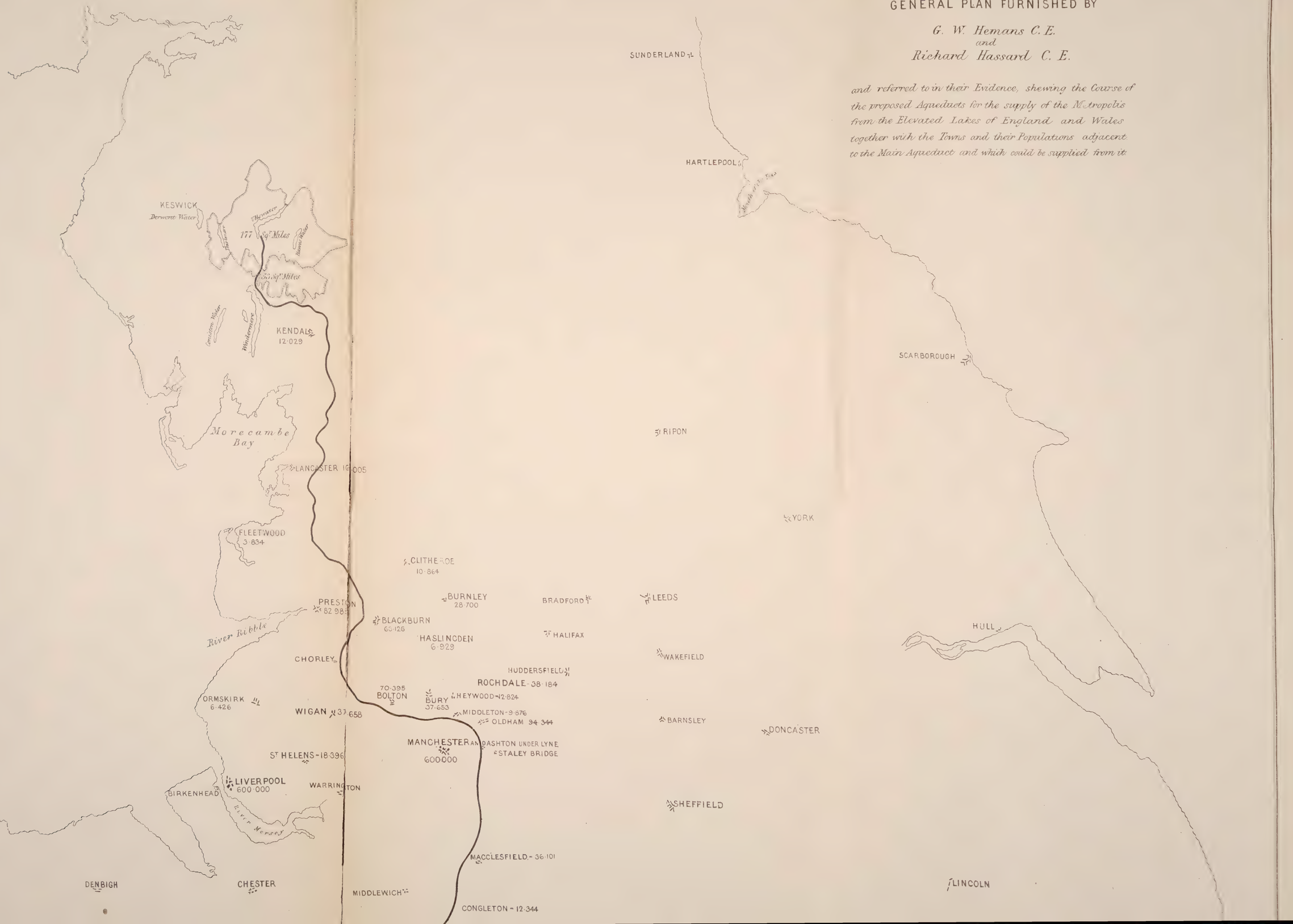
Appendix F, 2.

ROYAL COMMISSION ON WATER SUPPLY.

GENERAL PLAN FURNISHED BY

G. W. Hemans C.E.
and
Richard Hassard C. E.

and referred to in their Evidence, shewing the Course of the proposed Aqueducts for the supply of the Metropolis from the Elevated Lakes of England and Wales together with the Towns and their Populations adjacent to the Main Aqueduct and which could be supplied from it



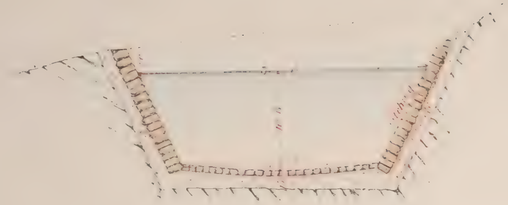
ROYAL COMMISSION ON WATER SUPPLY.

SECTION ON LINE OF MAIN AQUEDUCT FROM ULLSWATER TO STOCKPORT,

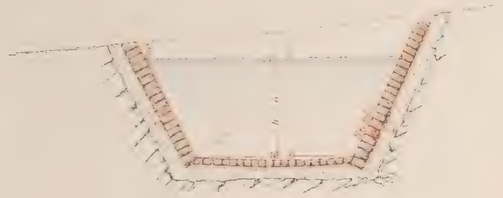
FURNISHED BY G.W. HEMANS, C.E. AND RICHARD HASSARD, C.E.

and referred to in their Evidence.

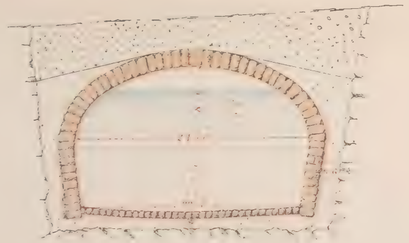
IN ROCK.



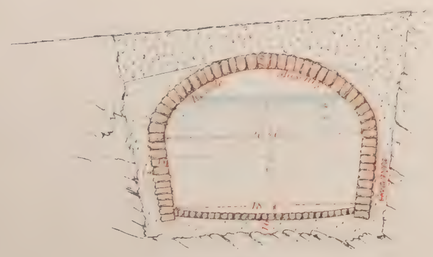
Fall 4 ft mile
Velocity 109.6 ft minute
Discharge 28.340 cf ft minute



Fall 6 1/2 ft mile
Velocity 128 ft minute
Discharge 27.702 cf ft minute



Fall 4 ft mile
Velocity 106 ft minute
Discharge 28.514 cf ft minute



Fall 6 ft mile
Velocity 127 ft minute
Discharge 28.575 cf ft minute

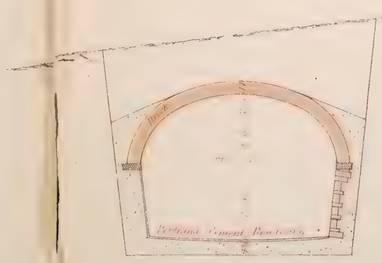
TUNNEL.

IN ORDINARY DISTRICTS.

Fall 40 in ft mile
Velocity 119 in ft minute
Discharge 28.760 cf ft minute.

Fall 40 in ft mile
Velocity 119 in ft minute
Discharge 28.760 cf ft minute

Fall 6 ft mile
Velocity 131 ft minute
Discharge 28.361 cf ft minute



Fall 6 ft mile
Velocity 127 ft minute
Discharge 28.575 cf ft minute

ROYAL COMMISSION ON WATER SUPPLY.

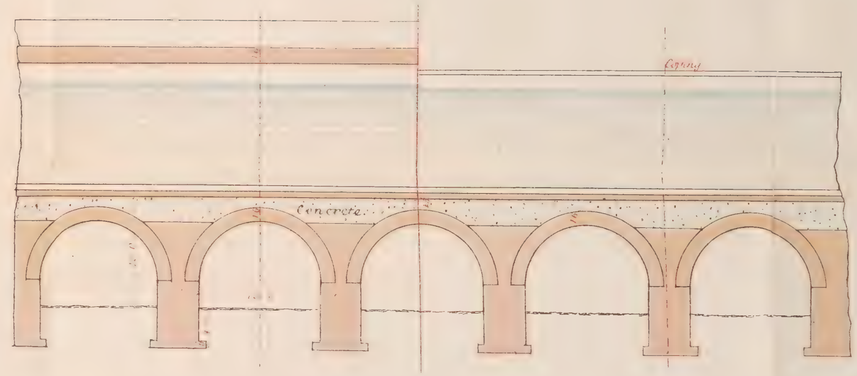
Sections shewing the modes of Construction proposed for the Main Aqueduct furnished by

G. W. Hemans C. E.
and
Richard Hassard C.E.

and referred to in thier Evidence.

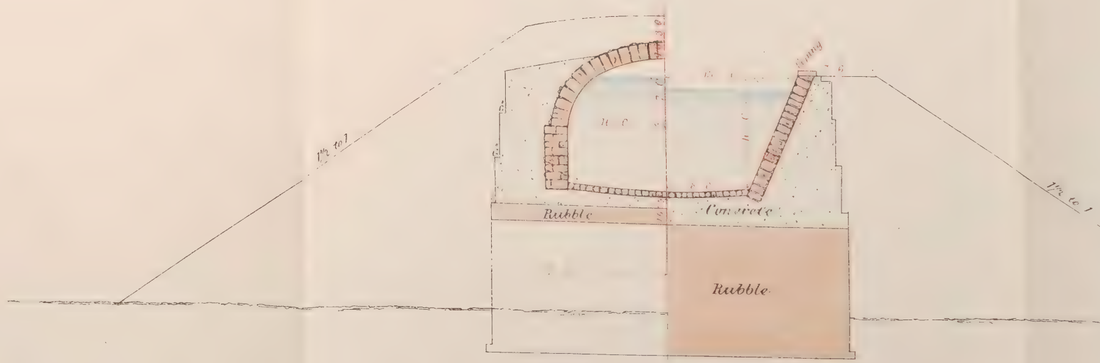
AQUEDUCT CARRIED ON SUBSTRUCTURE.

Longitudinal Sections.



Transverse Sections.

Closed. *Open.*



Fall 6 ft mile
Velocity 138.70 ft minute.
Discharge 27.750 cf ft minute

APPENDIX G.

Letter from Dr. Clark, on the Hardness of Water.

Clyde View, Partick, near Glasgow,

My Lord Duke, 30th October 1867.

If I take the liberty of addressing your Grace in your capacity of Chairman of the Royal Commission on the Supply of Water to the metropolis, it is as an old man of science that has performed a variety of service relating to the supply of water to towns, and for the benefit not of myself but of the consumers.

In order to explain the long and persistent interest I have taken in the supply of the metropolis with pure water, I may be allowed to state that happening to be in London so far back as the autumn of 1839, I accidentally saw a Parliamentary Blue Book, then just out, on the water supply of the metropolis. For the benefit of my pupils I had been accustomed to go rather fully into the treatment of water for the use of towns, and I procured the work, chiefly with a view to improving my lectures.

This Blue Book, however, opened to me a new field of information in regard to water for towns. The waters treated of were of the kind yielded by the chalk geological formation, of which hardly a trace occurs in Scotland.

Struck with the great hardness of the London waters, owing to the chalk they contain, the question occurred to me, how far hardness of this description could be got rid of? To this question I applied myself with diligence, and in the following March I was able to take out a patent for a process to soften chalk waters. In due time the specification was entered, wherein was first published a method of expressing hardness numerically in degrees, which since then has recommended itself to general adoption.

It is not my desire to intrude on your Grace with a discourse on water in general, but only to call your attention to a process for the purification of water that is of supreme importance in considering the question of the satisfactory supply of water to the metropolis. For this purpose it will be necessary to glance at the chemical composition and some of the chemical properties of chalk; for while chalk makes up the great bulk of the matter to be separated, chalk also contains the ingredient that brings about the separation. The invention is a chemical one for expelling chalk by chalk.

Chalk, then, for every pound weight of 16 ounces consists of lime nine ounces, of carbonic acid seven ounces. The nine ounces of lime may be obtained apart by burning the chalk, as in a lime-kiln, but may be subsequently dissolved in water in any quantity not less than 40 gallons. The solution would be called lime-water. During the burning of the chalk to convert it into lime the seven ounces of carbonic acid is driven off. This acid when uncombined is naturally volatile and mild; it is the same substance that forms what has been called soda-water, when dissolved in water under pressure.

Now so very sparingly soluble in water is chalk by itself that probably upwards of 5,000 gallons would be necessary to dissolve a single pound weight; but by combining one pound of chalk in water with seven ounces additional of carbonic acid, that is to say, with as much more carbonic acid as the chalk itself contains, the chalk enters readily into solution with water, and when so dissolved is called bicarbonate of lime. If the quantity of water containing the one pound of chalk with seven ounces additional of carbonic acid were 400 gallons, the solution would be a water of the same average hardness as well-water from the chalk strata, and not sensibly different in other respects.

Thus it appears that chalk, although naturally hardly soluble in water, may be rendered freely soluble in it by either of two distinct chemical changes, soluble by being deprived entirely of its carbonic acid, when it forms lime-water, and soluble by combining with a second dose of carbonic acid, making up bicarbonate of lime.

Now when we mix together these two varieties of solution of lime in water in such proportions as that the lime-water and the bicarbonate of lime contain each the same quantity of lime; for instance, when 40 gallons of clear saturated lime-water is mixed with 400 gallons of clear chalk spring water, each containing nine ounces of lime, the ingredients in solution combine so as to form two pounds of chalk, producing a sort of whitewash, which soon subsides into a powder of chalk, leaving clear pure water above. The following table will show what takes place when this change occurs:—

	Agents.		Products.	
Bicarbonate of lime	Chalk with Carbonic acid	16 oz.	= 16 oz. of chalk	2 lbs.
Burnt lime in 40 gallons of lime water		9 oz.	=16 oz. of chalk	

Rigid accuracy requires us to take into account the slight quantity of chalk that water can hold in solution, say a grain and a half per gallon = 1½ degrees of hardness.

In a year or two after the invention of this process, which was the last of a series of overworkings of the brain by the inventor during a period of at least 20 years, I was laid up and had the mortification of being permanently disabled from teaching. It was the year 1849 before my health permitted me to return to London. Ere then the process had attracted some degree of public attention. I had published a pamphlet that went through three editions, giving a popular account of the process and of its advantages. In 1851 a Government Commission was appointed to examine the "chemical quality" of the waters proposed for the supply of the metropolis. The Commissioners were Professor Graham (now Master of the Mint) and Doctors Miller and Hofmann. I am not aware of any Commission ever appointed by the Crown, to ascertain facts falling within the range of chemical science, consisting of persons more competent, or of higher scientific authority.

These eminent gentlemen were pleased to report thus:—

"In the judgment of the Commissioners *this softened chalk* "*water is entitled, from its chemical quality, to a preference* "*over all others for the future supply of the metropolis*" (Report, page 44).

It was not unnatural for an inventor that had laboured, I might say had sacrificed his means and his health, in order to render his invention efficient, to receive with gratification such an expression of approbation from such men: but how could he fail to be mortified when he subsequently beheld Government acting contrary to the opinion of eminent and impartial judges appointed by themselves?

The opinion of these eminent chemists has been amply verified by several erections of waterworks expressly for conducting the softening process. All these erections have been made, and most efficiently, by one engineer, Mr. Homersham. Not one of these works has proved a failure. The whole series might on the contrary be quoted as one of uninterrupted success. Three of the works are within an hour or two's journey from London, and I have no doubt that Mr. Homersham will be ready to facilitate to your Grace, or to any or all of the other Commissioners, the satisfactory inspection of any one or more of these works while in operation.

When I first invited public attention to the process for the use of the metropolis, I assumed that it would be river water, such as the Thames, that the process would naturally be employed to improve. But much about the time when the softening process was contrived the late eminent civil engineer, Robert Stephenson, had with his usual talent organized, matured, and defended a project for obtaining uncontaminated spring water for the supply of the metropolis from the chalky portion of the vast basin whereof London is the centre. Relinquished by Mr. Stephenson on account of his numerous engagements of another kind, and delayed by circumstances, this project gradually and worthily came into the hands of Mr. Homersham. He was the first to call my attention in 1849 to the expediency of confining in the neighbourhood of London the application of the softening process to spring chalk-water. Indeed the exclusion of the scourings of occasional showers, and the entire absence of animalcules and other organisms, are very signal advantages, and at once put a mark of superiority on the waters raised from the depths of the chalk. In spring chalk-waters the minute proportion of organic matter

destructible by a red heat, but previously removable by the softening process, amounts generally, according to my experiments, to about a full grain per gallon, so that the softened water is to this extent rendered more free from organic matter than the unsoftened spring water.

But it is not alone on account of the exclusion of rain-scourings or of organisms that spring water from the chalk derives its superiority, it is also on account of the prevailing temperature of the springs, which around London is generally about 50° Fahrenheit. Each spring keeps very near its own normal or standard temperature all the year through, whereas any river or other surface water, such as may now or may hereafter be brought into London, will in summer be too hot and in winter too cold for drinking, and moreover will in winter be liable to cool down below the freezing point, causing numerous burstings of the pipes by the freezing of the water they contain, and even by accidental explosions, so far as provision is made for heating the water for domestic use. This defect is inseparable from river and all surface waters introduced into towns, and attracts the less attention in the projects of waterworks, inasmuch as the expense of repairs thus incurred falls to be paid by the consumers and not by the companies. But apart from the serious expenses thus incurred, the damage to houses, the damp, the temporary interruption of all supply of water, are most serious drawbacks to any scheme of constant water supply. Spring water when passing through mains and pipes 4 feet underground, which is Mr. Homersham's practice, is free from any but rare and accidental instances of such defects. So treated the softened chalk-spring water is found all the year through not to rise above nor yet fall below the normal temperature of the spring more than six of Fahrenheit's degrees.

I shall be happy if your Grace deem these facts and considerations worthy of the attention of the Commission over which you preside.

I have, &c.,
THOS. CLARK.

To His Grace the Duke of Richmond, &c. &c. &c.,
Chairman of the Royal Commission on the
Supply of the Metropolis with Water.

APPENDIX H.

MEMORANDUM by Mr. JOHN BRAVENDER on the Upper Part of the Thames Basin.

As the subject of water supply to the inhabitants of towns generally, together with other sanitary improvements, has lately occupied public attention and is most certain to continue to claim more notice than ever, I hope to be excused for venturing to send you a few remarks and observations on the subject, and particularly with regard to the watershed of the Upper Thames, that is, of the country between the sources of the Thames and the city of Oxford.

The general course of the Thames is eastward. It is not derived from any defined spring at its head, giving out all, or nearly all, its waters, but is fed by many small rivers and brooks, most of them having their courses from the north and running southward, or having their courses from the south and running northward.

The Thames, according to the Ordnance map, commences at a place called Waterhay Bridge, about a mile below Ashton Keynes village, and about three miles west of Cricklade. The river, brook, or stream above this point is called Swillbrook, which is joined by a brook running from "Thames Head," past Kemble, through Somerford Keynes, and which joins the Swillbrook about a mile below Somerford Keynes village, and by another from Braydon, which joins the Swillbrook a little above Waterhay Bridge. The area of the watershed of this district, called "Swillbrook and Thames Head," is 74 square miles.

The following are on the north side of the Thames, and fall into it by taking generally a southward or south-eastward course:—

The Churn.
Ampney and Marston Brooks.
The Coln.
The Leach.
Small streams in Bampton district.
The Windrush.
The Evenlode, Glyme, and Darne.

Beyond the watershed of the Evenlode is that of the Cherwell, but as this river falls into the Thames below Oxford I have not considered it in the Upper Thames area.

The following are on the south side of the Thames, and fall into it by taking a northward or north-eastward course:—

The Ray.
Small streams in the Highworth district.
The Cole.

Beyond Faringdon the Ock has its rise and falls into the Thames at Abingdon below Oxford, and therefore beyond the district which I have named. The watershed of the Ock contains 100 square miles.

The springs of the watershed, containing 123 square miles, on the south side of the Thames, are not so abundant as from the same quantity of square miles on the north side of the river. The dip of the strata is south-eastward, and descending from the Thames on the south side, but towards the Thames on the north side. The surface slopes from the chalk hills towards the Thames, and the water which immediately runs off reaches the Thames, but at a slower rate than that from the north. Part of that which is absorbed by the soil, and part which is lost in the streams in the passage over open and porous beds, sinks through those porous beds to the upper surface of the tenacious beds of the Oxford Clay, Kimmeridge Clay, and the Gault, and the water descending the plane of stratification in a contrary direction to that of the river is lost to the Thames. The same remarks refer to the watershed of the Ock.

I have separated the district called Bampton from that of the Windrush and of the Evenlode, because the brooks and rivulets in it do not finally form a river of much larger size, and then pass on and into the Thames; but several small brooks take their course into the Thames without uniting, and this renders it incapable of being designated the watershed of any particular brook or river.

The same will refer to the district called "Hishworth."

The area of the watershed of the Upper Thames thus described is 875 square miles, and is made up as follows:—

	Square miles.
WEST OF THE THAMES.	
Swillbrook and Thames Head	74
NORTH OF THE THAMES.	
The Churn	73
Ampney and Marston Brooks	32½
The Coln	87
The Leach	36½
The Bampton and Thames district	119
The Windrush	141
The Evenlode	189
SOUTH OF THE THAMES.	
The Ray	65½
Highworth district	9½
The Cole	48
	123
	875

The rainfall over this 875 square miles may be taken at 28 inches per annum, from which 12 inches should be deducted for evaporation. The rainfall on a square mile, with this deduction, will be 1,376,000 cubic yards. But to arrive at the probable available quantity a further deduction should be made for percolation into porous strata which may not afterwards be thrown out by springs, and in consequence may not reach the Thames but pass under it. Some of this water we know must be brought to the surface by faults, as at Boxwell spring; but this can only be part of what percolates through the beds of the upper oolite to the surface of the fuller's earth. The water which is absorbed by the very porous beds of the under oolite is very large, amounting to a third of the rainfall.

The Churn, Coln, Windrush, and Evenlode, descend through valleys of denudation, the under oolite being cut through to some depth below the junction with the lias and a large quantity of the under oolite. Rainfall finds its way into those rivers by springs on the sides of the streams, and particularly by springs on the north-western side of the narrow valleys through which they pass; but some of this is liable to be absorbed again in its passage over the under oolite which occupies the beds of those rivers below the junction.

The loss by percolation through the upper oolite, including the forest marble and combrash, is to a considerable extent compensated by the immense discharge from the fuller's earth by Boxwell, Ewen, Ampney, and Bibury springs, which water, if not so discharged, would pass down the plane of stratification, and would not appear again in the vale of the Thames; and added to which must be reckoned half of the water pumped up from the fuller's earth by the engine at Thames Head. The summit level of the Thames and Severn canal extends from Daneway, at the western end of Sapperton tunnel, to Siddington, near Cirencester, being about 8 miles in length. From those two extremities the canal descends westward towards the vale of the Severn, and eastward to the vale of the Thames at Lechlade. The water being retained on the summit by means of locks, it descends in either direction about half to the Thames and the remainder towards the Severn. The principal loss in the watershed of the Thames occurs in the under oolite, the area of which is about 106 square miles. I have many years been aware of the great loss of water in the Churn, Coln, Windrush, and Evenlode, by passing over the open and rubbly rock of the under oolite, but until 1859 did not succeed in getting the occupiers of the mills on those streams to fix on the right cause. And this was not accomplished without a thorough investigation of the Churn, in which I lent a helping hand, and which finally established the views I had for years previously entertained. The observations were made in the autumn of a very dry summer, and the loss ascertained must be taken to be the maximum, and what the minimum may be is uncertain.

The average yearly loss I think is not less than half the rainfall, after deducting for evaporation, leaving 8 inches of available water. The available depth over the other strata in this watershed may be taken at 12 inches. The mean would appear to be somewhere between 9 and 11 inches.

Assuming it to be 9 inches only, and the inhabitants of London to be 3,250,000, then 272 square miles of watershed at this depth will supply them with 30 gallons each per day.

It will thus appear that the watersheds of the Churn, Ampney, and Marston brooks, the Coln, and of the Ock, amounting to 292½ square miles, will more than supply the entire population of London. The Churn, the Coln, and the Windrush, having an aggregate watershed of 301 square miles, are more than sufficient for the purpose, and the watersheds of the Churn, Coln, and the Ock, containing 260 square miles, are nearly sufficient for the purpose. London is at present said to be supplied with 643,000 cubic yards of water daily, which is at the rate of more than 33 gallons per head for 3,250,000 inhabitants. If this be correct, London is more abundantly supplied than many other towns.

But there is no necessity to provide the means of supplying the entire population of London. There are already eight or nine water companies, and I think to supply one-third, or to add one-third to the present means, would insure an abundance. In such case it would only be necessary to provide for 1,000,000 of the inhabitants. Eighty-four square miles of watershed will supply 1,000,000 people with 30 gallons per head per day. And to effect this there will require to be abstracted from the Thames directly, or intercepted at the confluence of the Windrush, a little more than half its water; or at the confluence with the Coln nearly all its water; or at the confluence with the Ock four-fifths of its water; or to be taken from the Churn and Ampney brooks, four-fifths of their waters. The water would have to be taken to London by an aqueduct, conduit, or pipes, and this may be accomplished without the help of steam or any other power. There is a fall from the mouth of the Coln to Paddington of about 3 feet per mile, which is sufficient to convey the water and distribute the same over any part of London which is at a lower level than Paddington by the force of gravity alone, which power costs nothing.

I think few persons will be disposed to doubt that by proper management under the Thames Commission this quantity can be spared from the river with little or no effect on the Thames itself.

I am prepared to show that with a very moderate expenditure the quantity of water descending the Churn and Coln may be greatly increased, and a very large quantity sent down to the Thames which is at present absorbed in the passage over the under oolite rock, which is very porous in this district. The increase which may be obtained from the Churn alone will be sufficient for more than 500,000 inhabitants, but which is now lost to the Thames.

The conveyance of this 84 square miles of rainfall to London may appear to present insuperable difficulties. There are difficulties, but I think not greater than those of an ordinary kind. For the purpose of carrying out this scheme I should recommend the formation of a new water company, whose engineers would soon show how to overcome the difficulties, if there are any.

In ordinary seasons there is an abundance of water in the Thames and its tributaries, but in times of a long continuance of dry weather it diminishes considerably, and in consequence storing will be indispensable in two of the following schemes:—

1. At a place called Langley Wear, near Appleton, in the county of Berkshire, and nearly opposite the place where the Windrush joins the Thames, about 7 miles below Witney, the water may be taken directly from the Thames and conveyed by conduit or otherwise in a straight line to near Didcot Station on the Great Western Railway, and thence by the side of the railway to Paddington.

By the Great Western Railway it is 53 miles to Didcot, and from Didcot to Langley Wear 9 miles, making the distance from Langley Wear to Paddington 62 miles.

The water may be stored for use in dry seasons at or near London, or at one or more places on the line of conduit between Langley and London.

2. At the confluence of the Windrush with the Thames the water of the Windrush may be taken and conducted to Paddington as above, and reservoirs for storing made either at the mouth of the Windrush, at or near London, or in both places, or at other places on the line between Langley and Paddington. The distance, as above, is 62 miles.

3. At the mouth of the Coln, about a mile above Lechlade, a reservoir may be constructed, into which may be conducted the waters of the Coln, the Ampney brook, and the Churn. Those rivers would have served all the purposes of the inhabitants on their courses previously to reaching the points where it will be desirable to divert them, and there would be no objection to the water being retained in a reservoir previously to the usual dry season of the year. The water may be conducted through the valley of the Thames to the previously mentioned point on the river called Langley Wear, and thence it might be taken to Paddington, as before stated. The distance from the mouth of the Coln is 72 miles, and the fall from Lechlade to Langley Wear 20 inches per mile, and from Langley Wear to Paddington 3 feet per mile. The mouth of the Windrush is very well suited for a large reservoir, and the mouth of the Coln is most favourable. The Cole joins the Thames at or near this spot, but on the opposite side, and in case of need could be made use of. Steam-engines might be placed so as to pump from the fuller's earth a little south-eastward of the "Thames Head," and the water thus obtained would descend through pipes to the reservoir at the confluence of the Coln with the Thames. It will be necessary to store up water for six weeks or more, and this may probably be done at both ends of the works, or at one end, or at intermediate places, to provide against unusual and extremely dry seasons.

The proposed lines of conduit will cross the river Ock at or near to Marcham Meadow Farm, 2 miles above Abingdon, at which place a large quantity of water may be taken and sent on to London if it should be required.

A million of inhabitants require 178,000 cubic yards per day, and 42 times this would have to be stored. Reservoir room would therefore have to be provided for 7,000,000 or 8,000,000 cubic yards of water. Should larger reservoir accommodation be necessary it may be had to any extent. It is only a question of expense.

The impurity of the water of the Thames has been spoken of by writers on the subject, but the passing of a recent Act of Parliament will tend greatly to remedy this. The smaller towns on the tributaries beyond the three-mile limit are preparing for the disposal of the sewage by other means than letting it descend into the streams running near or through them.

I should think that any company formed for the purpose of supplying this million of the inhabitants of London would be willing and could afford to pay an acknowledgment to the Thames Commissioners for the privilege and as compensation for being allowed to take this water from

the Thames. The quantity to be taken per annum would be more than 65,000,000 cubic yards, and the payment of a very small fraction per yard, say one penny for 90 cubic yards, would create a revenue of 3,000*l.* a year. The yearly income of a water company at 5*s.* per head for a million of people will be 250,000*l.*

This 3,000*l.* a year would enable the Thames Commissioners to improve the river, and in doing so very greatly to improve the lands on its banks. This would be a beginning; but the works should not be limited to an outlay of a small sum per annum to effect the improvements to which the Commissioners should direct their attention.

The river from Cricklade to Oxford should be straightened, deepened, and in some places widened, and the inlets of all rivers, brooks, and streams would have to be deepened to correspond on both sides for some way up their course. Without going over the ground it will not be easy to say what the cost of these things will be or ought to be, but I have an idea that 140,000*l.* or 150,000*l.* would carry out what is here indicated. This money would have to be borrowed, and reckoning at four per cent. on 140,000*l.* the interest would come to 5,600*l.* per annum. A rate of 2*s.* 3*d.* per acre on 50,000 acres of land between Cricklade and Oxford, which would be greatly improved by the works, will amount to 5,625*l.* This would be a very moderate charge on the land, the greater part of which would be increased in value to the extent of from 5*s.* to 1*l.* per acre per annum. The rate would have to be risen on the lands in proportion to the extent of the improvement of each field by the works, and not on an average of the district to which the operations may extend.

The 3,000*l.* a year which is proposed to be derived from a future water company would meet the official and other expenses, and leave something to form a fund for future repairs, extensions, and improvements of the works, and any excess might accumulate and be used from time to time in reducing the borrowed capital.

JOHN BRAVENDER.

Cirencester, April 1867.

APPENDIX I.

(REPRINT OF PAMPHLET.)

On a CONSTANT WATER SUPPLY for LONDON.—By JOHN FREDERIC BATEMAN, Esq., C.E., F.R.S., F.G.S., &c.

(*Reprint of a Paper read at a Meeting of the Health Department of the National Association for the Promotion of Social Science, Monday, January* 21*st*, 1867.)

THE question of "Constant Water Supply" is one which has been agitated, not only recently, but on many previous occasions in London, and in those places where the opposite system of "intermittent supply" has been the mode usually adopted. I have been requested to read a paper upon the subject; but as my experience lies almost wholly with the system of "constant supply," I can do little more than state how far it has been successful, and what are its results in the cities and towns with which I am acquainted, and describe what are the difficulties with which a town has to contend when the supply is changed from the "intermittent" to the "constant" system. Coming before you as a comparative stranger, known only by name, but probably presumed to have a certain amount of professional knowledge upon the subject, it may be expedient that I should state to you what my experience is, that you may be able to judge of the value to be placed upon the observations I may make.

I first constructed works for the supply of water to towns nearly 30 years ago—since which time I have constructed, in whole or in part, the waterworks of some 25 or 26 different towns and cities, varying in size from 7,000 to 600,000 persons, and containing a gross population of upwards of 2,000,000. I have, besides constructing these works, been consulted in one way or another upon a great number of the waterworks of the country, which have been in the charge of other engineers, during the period named, and I ought therefore to know something of the subject, unless I have made very bad use of my opportunities.

My experience commenced in the manufacturing districts of the north of England, and at the time of its commencement, 25 or 30 years ago, the question of water supply was in a very crude condition. The system commonly adopted, however, even then, in that part of the country, was that of "constant supply," and in my early experience I neither thought of nor knew anything of any other system. In all the towns that I have supplied there are, I believe, but three which at the present time give an intermittent supply of water, and these are towns in which waterworks existed, and the intermittent system was established, before I had anything to do with them. In one of these, the town of Belfast, the system will be discontinued as soon as new works, now being constructed, have been completed. In many places, and most importantly, those of Manchester and Glasgow, I have been instrumental in changing the mode of supply from the intermittent to the constant system; and it is my experience specially with reference to these cities and the change of systems that I shall endeavour to lay before you.

The question of constant supply is one which most materially affects the comfort and convenience of the poorer classes, and the inhabitants of smaller houses. In larger houses ample cistern space is generally provided, to secure the equivalent of a constant supply; but where water is constantly laid on from the street mains, there is scarcely any occasion for house cisterns, except for the supply of water-closets. By proper arrangement, little or no inconvenience is experienced from the occasional shutting off of water for the changing or attaching of house services. The first cost of introducing the water to the houses is reduced to the lowest possible point, and the pollution which more or less commonly attends the storage of water in house cisterns is entirely prevented; the water is delivered in the purest, freshest, and coolest condition; and very much of the annoyance and inconvenience arising from frozen cisterns and burst pipes, which are the common attendants of the winter season, is avoided. There is no occasion for exposed pipes in out-of-the-way places—for cisterns in roofs or on the tops of houses, to be filled with soot and dust in summer, and to be frozen in winter; and a man may live in tolerable comfort, without the dread of the water bursting above his head, and deluging the apartment in which he resides. But the advantage of constant supply to the consumer has been so often and so clearly demonstrated, that it is useless to dwell further on this branch of the subject. The question of its adoption does not entirely rest with the consumers, but with those who have to provide the water. It is believed by many, that the consumption under the constant supply system is so great, that no company or waterworks can meet the demand—it would be ruin to them if they attempted it. I cannot but think that all this is a delusion; it is not that more water is actually consumed for the use of the individual under the one system than under the other, but that the amount of *waste* which results from bad pipes and bad fittings, constantly supplied with water, is so great as to occasion serious loss and inconvenience to a water company, and perhaps in some cases to exhaust their supplies. The experience of those towns in which the supply has always been on the "constant system," and where every precaution has been taken for the purpose of securing good workmanship, the best and strongest materials, and the most improved apparatus, is, that the consumption of water per head is certainly not more, probably less, than it is in towns similarly circumstanced in all other respects, but supplied with water on the intermittent system. This is abundantly proved by the statistics of water supply in such places. For instance, the average consumption of water in the manufacturing towns of Lancashire and Yorkshire is from 16 to 20 or 21 gallons per head per day for all purposes, including trade, and of course all the waste which may be taking place. In Manchester, the quantity consumed by about 600,000 persons, and by the trades demanding water within the district supplied, varies from 12,000,000 to 13,000,000 gallons per day. Of this quantity, it is estimated that one-third is supplied to manufacturers, leaving the net quantity consumed for domestic purposes, including waste, 14 gallons per head per day.

The experience of Preston, Blackburn, Bolton, Stockport, Halifax, Warrington, and almost all the other manufactur-

ing towns in the north of England is nearly identical with that of Manchester—and if this be compared with the consumption which obtains in towns supplied under the intermittent system, it will be found that scarcely in any case does the supply fall to so low a point as under the constant system.

In London it is 32 gallons per head per day, and in Plymouth, Devonport, Shrewsbury, Oxford, and other places supplied on the intermittent system, the consumption amounts to 30 gallons or more per day.

The quantity required in different towns no doubt varies according to the class of inhabitants, the circumstances, and the habits of the people, and it is universally found that where water-closets exist as a general rule, the consumption is greater than where they are comparatively absent.

It may be well, therefore, to adduce a few examples of what is actually required for domestic use.

We have shown that in the manufacturing towns with an unlimited and unstinted supply, 14 gallons per head per day are all that are taken for domestic use. In Preston, careful observation and measurements, continued during many years, proved that 10 or 11 gallons were sufficient. But in these towns generally the number of water-closets is small.

The results of a few experiments which were made in Sheffield some six or seven years ago will be instructive. Two groups of cottages and a single mansion were selected for experiment; the water was constantly laid on; in one case the consumption was taken by actual measurement, by means of a cistern, and in the other two cases by a water meter. The experiments were made without the knowledge of the inhabitants. One was a case of 16 cottages, containing 83 inhabitants, and in these the average consumption upon a fortnight's trial was 7½ gallons per head per day. The second case was a group of four houses each of about 25*l.* a year rental, containing 26 inhabitants, and here the consumption for a similar period was at the rate of five gallons per head per day. The third was that of a large mansion with 13 inmates, a bath, and two water-closets; here the consumption was at the rate of 11 gallons per head per day. The average consumption in the town of Sheffield, including the supply to trade, was 20 gallons per head per day; deducting the trade supply as ascertained by meter, it was 18 gallons per head per day; but the pressure in Sheffield is, with perhaps two or three exceptions, greater than that of any town in the kingdom, and any leakage therefore which might have existed, and which of course would be included in the 18 gallons per head per day, would be much greater than in a town where the pressure does not exceed that to which pipes are ordinarily subjected.

Other instances of what is actually required will be given when we come to treat of the prevention of waste; but it must be clear that there is nothing in the system of constant supply which would necessarily create a larger consumption of water than in that of the intermittent supply. Anything beyond the proper normal requirements of the inhabitants, which would be amply met by from 15 to 20 gallons per head per day even in a town largely supplied with baths and water-closets, is chargeable to defective pipes or defective arrangements and fittings: and now we come to the real difficulties with which the system has to contend.

On this point and on the extent to which waste may be reduced, I can give several useful examples.

In Cambridge, where the supply has always been constant, but where precautions against waste were neglected till recently, the following facts are exhibited, for which I am indebted to Mr. Tomlinson, the manager. In the first half-year of 1865, at which time no preventive measures had been introduced, the gross consumption per head per day was 31·2 gallons, and the domestic consumption, after deducting water sold for trade purposes, 23·1 gallons per head. A house to house inspection was then carried out—all bad cocks were replaced by those of the best construction, and water-fittings of every description were put into proper repair. The result was, that in the first half-year of 1866, the gross daily consumption was reduced to 19·56 gallons per head, and the domestic consumption to 11·1, being less than one-half of what had previously obtained.

At Newcastle-on-Tyne the water has always been delivered on the constant supply system; but the consumption gradually increasing to an extravagant point, a vigilant inspection was introduced, and means taken for checking the wasteful expenditure of water, sufficient powers having been granted to the company by a recent Act of Parliament. Mr. Main, the very intelligent manager of this company, writes me as follows:—

"Our gross daily consumption is 30 gallons per head, of which seven gallons go to manufacturers and trade. Considering 23 gallons per head to be excessive for domestic consumption, I was anxious to ascertain precisely where the water went to. For this purpose I had the town divided into small districts of three or four streets completely isolated, and put on a street meter to register the daily consumption. On comparing the results in districts where water-closets prevailed with those in which there were none, or comparatively few, it was soon apparent that the water-closet, generally from being out of order, but in several cases from the crank handle being purposely propped up, was the great consumer. The following are a few of the results:—

	No. of Inhabitants.	Water Closets.	Consumption per head per day.
1. Eldon Square - - -	170	29	70 Galls.
2. Leazes Terrace - - -	275	47	71 ,,
3. Rye Hill and adjoining Streets	880	118	55 ,,
4. Framlington Place and do. -	770	124	80 ,,
5. North Parade and do. -	725	173	60 ,,
6. York Street and do. -	190	25	61 ,,
7. Lancaster Street and do. -	145	12	62 ,,
Prudhoe St. and adjoining strts.	1575	10	11 ,,
Thornton Street and do.	1930	None.	23 ,,
Abinger Street and do.	1595	33	30 ,,
Shield Field District - -	4845	138	21 ,,

"In order to stop so flagrant a waste we set on a staff of men to examine every water-closet and tap, and report them, leaving a notice, that if not put in order within three days, the supply would be stopped, After the lapse of three days, another set of men followed, inspecting only those places reported as leaking, and shutting off the water where the notice had been disregarded. In this way we stopped an immense waste, the effect being immediately apparent in increased pressure throughout the town. But that measure was only for a temporary purpose, and could not be relied upon to effect any permanent saving, and for upwards of twelve months we have been going on systematically replacing the present water-closets with Guest and Chrime's double-valve cistern, and Thomson and Murray's valve cistern, neither of which can be propped to cause a continuous run. In this way we have reduced

"No. 3 District from 55 to 34 gallons per head.
5 ,, ,, 60 ,, 39 ,, ,,
6 ,, ,, 61 ,, 25 ,, ,,
7 ,, ,, 62 ,, 26 ,, ,,

"The others are not so complete that I can give you the results accurately.

"In carrying out the change, we occasionally meet with opposition, but not as yet to any extent. In one district we put new double-valve cisterns into every house by arrangement with the landlords. The result was as follows:—

"Tyneside Terrace and Mitford Street—number of inhabitants, 930; water-closets, 86.

"Before the improvement the meter registered (from December 20 to March 22) 2,771=32·4 gallons per head per day.

"After the improvement (from April 12 to June 26), 1,160,020=16·6 gallons per head per day."

In a subsequent letter, dated the 17th of this month (January 1867), Mr. Main writes:—

"I now subjoin particulars of a large district, consisting entirely of tenemented property where several tenants are supplied at one tap. You are aware how large a proportion of Newcastle consists of property of this description, and I was anxious to show you the results of our improvements in a district different from any of those previously given.

I may mention that the overhaul in this large district has been more thoroughly carried out than in any other.

"Diana Street and adjoining streets—number of inhabitants, 5,605; water-closets, 60.

"Consumption per head per day before improvements in water-closets and taps, 31 gallons; after improvements, 12 gallons."

The small consumption which generally prevails in the manufacturing towns of the north of England may, to a great extent, be owing to the custom which has commonly been adopted by the water companies and several of the corporations of doing their own plumbing work.

It is their interest to employ pipes of such strength and fittings of such approved construction, and to execute their work in such a manner as to prevent as far as possible all waste from leakage and bad taps. They do their plumbing, therefore, not for the purpose of carrying on a lucrative trade, but for securing thoroughly good materials a

workmanship, and the best results to all parties have followed.

Shortly after the introduction of a new and ample supply of water into Manchester in the year 1850, the old system of intermittent supply was superseded by that of the constant system; but it was only gradually introduced. The city was divided into small districts, and all means were taken for seeing that all the pipes and water-fittings were of the best description, and suitable for use under the constant supply system, before the inhabitants were allowed to enjoy that advantage. At my suggestion, the corporation in whose hands the water supply was, adopted the plan so successfully pursued in other towns of being their own plumbers, but the clamour and opposition of the plumbers of the city was too much for popular representation, and the system was gradually relaxed. They discontinued the plumbing, but they established a warehouse or shop for the sale of fittings, purchasing the very best, and, as far as possible, compelling the plumbers to purchase from them, allowing the adoption of none which were not approved.

After a time this was discontinued, and a certain number of plumbers were licensed, or authorized to do the requisite work on certain conditions—with which they were obliged to comply. These regulations are still continued, and there is probably no great water supply in the world, which is administered with as little waste and with as much convenience and comfort to the inhabitants.

It will be thus seen, that where everything is in good order, and both the water provider and the water consumer do their respective duties properly, there is no disadvantage to either party by the supply of water on the constant supply system—while the advantage to the consumer, in the facility with which he obtains water, and the trifling cost at which it can be introduced into his premises, are incomparably greater than can be enjoyed under the other system. Where, however, the intermittent system has hitherto prevailed, the desirableness, and, indeed, practicability of abandoning it, and adopting the constant supply, depends very much upon the consumers. If they will submit to such regulations as are necessary for preventing waste, there can be no difficulty in introducing constant supply—it will consume no more water than the intermittent system. The only changes which are required, are the abandonment of all bad fittings, such as common ground taps, leaky cocks, and wasteful waterclosets. The cisterns, already existing in houses which have been adapted to the system hitherto employed, may remain, if it be the will of the owner or occupier that they should. If they are large enough they do now practically give a constant supply, and it is only just to the provider of water, that care should be taken to prevent improper use. Those who prefer to abandon their cisterns and to take their water direct from the pipes, can do so at very little expense. In all new buildings there would be no necessity for the expensive paraphernalia of cisterns; a stopcock on the service pipe of the house would enable the water to be turned off whenever repairs or alterations were required to be made within the house. Little inconvenience is felt by grouping a number of houses together, commanded by one stopcock; and indeed, it may be said, that complaints of inconvenience arising from interruption to the supply of water, are scarcely ever heard in towns where the constant supply is at work. If the public will not submit to introduce the best description of fittings, and to prevent waste, and will not subject themselves to the vigilant inspection which ought to be exercised by the provider of the water, and be willing to correct everything which requires correction, it will be difficult and, in some cases, impossible to introduce the constant supply.

About 10 or 12 years ago, the city of Chester was supplied upon the constant system, after the inhabitants had been long accustomed to the intermittent. The company gave ample notice of their intention to change the system, and earnestly invited the inhabitants to co-operate with them in preventing waste. This call was not responded to by the consumers, and the result was that the consumption increased so much, that the pumping engines, which upon the intermittent system, were capable of affording all the supply required by working 12 hours a day, were compelled to work night and day, in order to supply what was required upon the constant system. The company were obliged in self-defence to return to the intermittent mode—on which the city is now supplied. This, however, is the only case of failure in my experience, and it may perhaps be accounted for by want of proper or resolute determination on the part of the company in bringing offenders to justice.

I must not omit, however, to notice the great consumption of water which obtains in many of the Scotch towns, and notably in the city of Glasgow. There, under both the intermittent and constant system, the quantity supplied has been enormous; but it is easily accounted for and might be remedied.

Under the old system of a partially-intermittent supply—when the water was pumped from the Clyde, the gross consumption was at the rate of 40 gallons per head per day, 36 gallons of this being due to domestic consumption and waste, the latter element being mainly chargeable with the extravagant consumption.

When re-arranging the piping for the reception of the water from Loch Katrine, I felt it important to draw the attention of the corporation to the large consumption, and to the growing habits of waste; and I cannot more clearly explain my views than by reading a portion of a report which I had occasion to make on the re-arrangement and extension of the city piping in February, 1858. In this report, after alluding to the state of things which existed, I say:—

"I will not enter into the question of whether 'constant supply' or 'intermittent supply,' as they have been respectively termed, is the best system for the supply of a town. It is your intention to give the inhabitants the full advantage of the Loch Katrine water constantly laid on, and from the elevation of the Mugdock reservoir, always at high pressure.

"The two systems have each been warmly advocated, but my observation and experience lead me to the conclusion that the 'constant system' when properly regulated, is much the most convenient on the whole—the least expensive to the tenant, and not more costly either in works or water than the other. It is no new or untried arrangement, as has been erroneously supposed, for it is the common mode in which most of the large manufacturing towns of the north of England have been supplied for the last 30 years.

"Where this system has always been the one adopted, or where it has been in existence for a considerable period, with everything in good order and under vigilant regulation, the consumption of water is, I believe, less than it would be in the same town under the intermittent system, supposing that in both cases an unstinted supply be given; but where a change has to be made from the 'intermittent' to the 'constant' system, very great waste is commonly the result, and it requires the utmost vigilance, and the most persevering attention, and, indeed, severity, to prevent it.

"Under the intermittent system people become negligent of the state of repair of their pipes and water fittings; they keep their taps constantly open, and are heedless about the waste which frequently takes place during the periods of the water being laid on. The water-works officials generally wink at this state of things, from a feeling that the waste only takes place within a limited area, and for a limited number of hours, and that it is effectually prevented during such periods as the water is wholly shut off.

"Should, however, the same state of things exist under a system of constant supply and at high pressure, the waste would be enormous, and even Loch Katrine would be found inadequate to meet it.

"In introducing the constant supply, therefore, where it has never been in use before the inhabitants should be previously prepared by due notice of the time at which it would be commenced, by imperative injunctions to put their pipes and taps into good order, and to abandon the use of all vessels for collecting or storing water, except those properly furnished with ballcocks. These injunctions should be followed by the most active supervision and by the most unmitigated severity of which the law admits, in all cases of neglect. By degrees the inhabitants would become accustomed to the new system, and after a time it would work harmoniously and advantageously for all the parties interested.

"These observations apply only partially to Glasgow, for in Gorbals, and over a large portion of the city north of the Clyde, the supply has for a long time been constant; but there are districts in which the intermittent system still prevails, and over the whole city the pressure and the consequent waste from bad fittings will be materially increased."

Then, with reference to the waste from water-closets, I say in the same report:

"Nothing can be a greater luxury than a well-kept water-closet perfect in all its parts and appurtenances, properly separated from the living rooms of a house; and in a rich man's residence, or in the hands of those who will spare no labour nor money to erect them first, and to maintain them afterwards in perfect efficiency, it is no doubt the

ne plus ultra of comfort, convenience, and cleanliness. But all who are in the habit of using them know how much trouble there is to keep them right, how frequently they go out of repair, and what a terrible nuisance it is when they do. Careless housemaids will put down mops or brushes, spoons or cinders, just as it may happen; working apparatus will get out of order, and soil pipes and drains will occasionally become stopped. These inconveniences, however, occurring to a man who can afford it, may be rectified by pains and money, and they do not amount in such case to an argument against the use of an arrangement which possesses so many counterbalancing recommendations and advantages. But change the scene to the house of the poor man, or to the dwelling of one who is careless of personal comfort, or perhaps of decency, and all these inconveniences become evils of very serious magnitude. There is seldom space enough properly to separate the water-closet from the apartments in which the family live, and if it gets out of order it will either be carelessly neglected, or it will cost money to repair which cannot be afforded. If the arrangement admits of it most likely the water will be kept constantly running, and the soil-pan open—the effect of which is to waste the water and to permit the free escape of all noxious effluvia from the drains and sewers into the ill-ventilated apartment in which the family resides. Nothing could be more perfectly contrived for poisoning the atmosphere and engendering disease. Nor is this all. The habits of the lower orders are such as to render a state of disrepair a thing of more common occurrence with them than amongst the upper classes. It is the readiest receptacle for anything that has to be thrown away, and the absence of toys and amusements amongst the unfortunate, cribbed and cabined children of the poor affords a strong temptation to resort to so capital a substitute as the plug of a water-closet, the unconscious little urchins never dreaming that on every repetition of their fun in opening and shutting the pan they allow the escape of poisoned air.

"The ordinary water-closet, under the best of circumstances, is generally productive of much waste of water, and if the cistern supplying it be also furnished with a waste-pipe, the water running away imperceptibly and uselessly may be very considerable.

"I would, therefore, respectfully beg your attention to this subject, both on account of the cost of the water and the health of the city, and urge you to institute very active supervision and the compulsory use of apparatus of the most approved construction, so as to reduce or remedy the evils I have pointed out. Many amongst the poorer classes are no doubt as careful to have everything in good order and as clean and sweet as their richer neighbours; but I apprehend this is not the ordinary rule, and much improvement must take place in the habits of the lower orders generally before these remarks are altogether inapplicable."

Then, as to cisterns :

"A further active agent in waste is the old system of cisterns, which is the necessary accompaniment of an intermittent supply, and which therefore prevails over the whole city—Gorbals to a great extent included—in consequence of the diminution of pressure in the pipes.

"The use of cisterns is, I believe, indispensable at present, and under any system of supply they are attended with so many advantages and conveniences, that it may frequently, perhaps generally, be desirable to retain them. Under constant supply, cisterns are not absolutely necessary, except to water-closets; but as they have the effect of lessening the pressure, the waste from bad taps and imperfect fittings is reduced by their use, if they themselves are properly fitted up with unexceptional ball-cocks to shut off the water when the cistern is full. If this is not attended to, the water which may pass off unperceived from the waste pipe of the cistern may be very considerable; and, as the cisterns are frequently placed on roofs and in other inaccessible places, they are not easily inspected and are never visited except in cases of necessity."

But one of the great causes of waste in Glasgow was the wretched character and condition of kitchen taps and the water-fittings generally. A rather startling account of these elements of waste was contained in a report prepared from careful observations and measurements made by Mr. James M. Gale, in Gorbals, in 1850, and on this report I made the following remarks :

"From these, it appears that the average daily waste by 135 families from badly constructed or imperfectly fitting kitchen taps alone, amounted to 108 gallons per family, or 20 gallons per head per day.

"In one staircase, while one careful man wasted nothing, another negligent fellow ran down his sink-stone, for no useful purpose to himself, no less than 850 gallons a-day.

"This waste is principally caused by the universal custom in Glasgow of using the common ground tap—the worst description of tap for water under pressure which can be adopted, and which has long since been exploded in all improved and well-regulated waterworks in England."

No great attention was paid to the workings which this report contained till after the introduction of the Loch Katrine water.

This took place at the close of 1859, and by March 1860, the whole city north of the Clyde was receiving this water. On the 6th of June, only three months later, I felt compelled to make the following report :—

"I must draw your attention to the present consumption of water, which is increasing so rapidly as to be really alarming, and quite warrants the apprehensions I felt, and the pains I took to guard you against it, when writing my report on the city piping in February, 1858. Referring then to the habits of waste which existed, and to the imperfect state of the water fittings, I observed that 'should the same state of things continue under a system 'of constant supply, and at high pressure, the waste would 'be enormous, and even Loch Katrine would be found 'inadequate to meet it.' At the time I wrote this, the consumption on the north side of the river was a little under 13,000,000 gallons a-day. In November last, 18 months later, it had increased to 14,000,000 and in the beginning of March of this year, after the whole of the city on this side was supplied with Loch Katrine water, it war 15,000,000 gallons per day. It has gone on increasing since then, till it now amounts to 18,000,000 gallons per day, being an increase of 3,000,000 gallons a day in three months. The consumption by the city was measured at the Mugdock Reservoir every hour for twenty-four hours consecutive, in the beginning of this week. The greatest draught is about 1 o'clock in the day, when it is at the rate of 22,000,000 gallons a-day, and the least at 2 o'clock in the morning when it amounts to about 14,000,000. At this time of the night, nearly the whole of this quantity must be wasted.

"The total consumption of the city from Loch Katrine and Gorbals together is 22,000,000 gallons a-day, being at the rate of about 50 gallons per head, and just twice in gross quantity as much as Manchester and Salford take for a larger population."

Upon this statement Mr. Gale, the resident engineer, was instructed to institute such an examination as would lead to the discovery of the cause of the excessive waste of water. He found that from badly-constructed and leaky taps alone the waste amounted to 7,200,000 gallons per day, equal to 20 gallons per head, the value of which, if sold for trade purposes, would have been about 50,000*l.* per annum.

What followed after this will be seen from a report I addressed to the Water Committee in January, 1862 :—

"I must again draw your attention to the rapid increase in the consumption of the water. The city on the south of the Clyde has exhausted its own supply from the Gorbals works, and is now assisted by a supply from Loch Katrine.

"The gradual increase in the city north of the Clyde has been as follows :—

"In the beginning of 1858, the daily consumption was 13,000,000 gallons. In November, 1859, just before the introduction of Loch Katrine water, it had risen to 15,000,000. In March, 1860, the whole of the city north of the Clyde was supplied from Loch Katrine, and by June the consumption from that source had arrived at 18,000,000 gallons per day.

"I then brought the subject prominently under your notice. Careful investigations into the causes of waste were made by Mr. Gale, by your directions. He found that no less than 7,200,000 gallons a-day were run to waste by leaky and bad taps alone, a quantity which he estimated at a money value of 50,000*l.* per annum. Stringent supervision was introduced, and other measures taken for remedying this enormous evil, and by October the quantity had been reduced to 13,000,000 gallons, being a saving of 5,000,000 gallons a-day in three months.

"At this point the consumption remained for a few months, but it is again steadily on the increase. At the commencement of 1861, it was in round numbers the same as it had been brought down to in October—viz., about 13,000,000 gallons a-day. It was maintained at this low point, to some extent, by so closing the valves as to reduce the pressure in the lower parts of the city to what was equivalent to only 70 feet in height, thus throwing away the advantage of high pressure, for the extinction of fires and for other purposes.

"By Midsummer the consumption had increased to 15,500,000 gallons. In August the Loch Katrine water was turned on to the west end of Gorbals, and in September the pressure in the pipes during the night was increased to about 140 feet. These arrangements, and a recurrence, no doubt, to the old habits of waste, brought up the consumption to upwards of 17,000,000 gallons per day, which added to the supply from the Gorbals works, made the total daily quantity supplied to the city 21,000,000 gallons, or 46⅔ gallons per head per day on the population of 450,000 who are supplied by the two works.

"Here is an increase in one year of 4,000,000 gallons per day."

There is a further report on this subject from Mr. Gale in November, 1864, giving the details of inspection and the then condition of the taps and water fittings. Special regulations had been established for the introduction of improved apparatus, but there still remained 41 per cent. of those in use which were not consistent with these regulations.

This case of Glasgow will no doubt be much relied upon by the opponents of the "constant supply system;" but the extravagant consumption is clearly due to causes which may be remedied, and to the fact that the Corporation have never resolutely and perseveringly set to work to apply the requisite remedies. The people of Glasgow look upon Loch Katrine as practically inexhaustible. The works are constructed on a scale for bringing more than twice the quantity now used. They are their own property, and as the water is supplied by gravitation, the excessive waste which takes place costs them nothing at present.

I see no reason to doubt that if in this great metropolis the providers of water and the consumers of water will each do their duty and work harmoniously together, the citizens may enjoy the inestimable benefit of an unlimited supply of water, constantly laid on, without consuming a gallon more water, if indeed as much as is now supplied by the water companies.

APPENDIX K.

MEMORANDA of the Cost of PUMPING and FILTRATION.

Southwark and Vauxhall Water Company,
Office, Sumner Street, Southwark, S.E.

MY DEAR SIR, 27th February 1868.

I FIND the cost of raising 1,000 gallons of water by this company, 100 feet high, is between $\frac{1}{6}$ and $\frac{1}{7}$ of a penny, or 13*s.* 10*d.* per 1,000,000 gallons, including coals, oil, and tallow, wear and tear, &c.

Yours very truly,
JOSEPH QUICK.

T. Harrison, Esq., C.E.

Southwark and Vauxhall Water Company,
Engineers' Office,
Sumner Street, Southwark,

SIR, 20th March 1868.

IN reply to the question contained in your letter of the 11th inst. as to the cost of pumping water by this company to a height of 100 feet, I beg to state that the sum named included the expense of coals, oil, tallow, labour, and ordinary repairs.

The cost of filtering water, including labour, scraping, cleansing, and renewing sand is $\frac{1}{14}d.$ (one fourteenth of a penny) per 1,000 gallons, exclusive of interest on capital.

I am, &c.
JOSEPH QUICK.

Dr. Pole, &c. &c.

29, Great George Street, Westminster, S.W.

DEAR SIR, 24th March 1868.

IN reply to your inquiry I estimate the cost of pumping per million gallons 100 feet high at 1*l.* 0*s.* 3*d.*, including coals, tallow, oil, and other stores, labour, repairs, &c.

And the cost of filtering at 5*s.* 4*d.* per million gallons, including labour, cleaning, and sand for renewal.

I am, &c.,
JAMES SIMPSON.

Wm. Pole, Esq.

APPENDIX L.

RETURNS as to the CAPABILITIES of the METROPOLITAN WATERWORKS, drawing Water from the Thames, for increasing the Quantity of Water taken.

The following letter was written to each company.

11th March 1868.

I AM desired by this Commission to ask the favour of your informing them,—

Whether the works of the Company are calculated to take from the Thames a larger quantity than at present? and if so, what is the maximum daily quantity you could pump, filter, and deliver into your distributing reservoirs, without materially adding to your present capital?

Any further outlay necessary for increased storage and distribution need not be considered.

I am, &c.
(Signed) WILLIAM POLE, Secretary.

To this letter the following answers were returned.

29, Great George Street, Westminster,

SIR, S.W., 24th March 1868.

IN reply to your letter of 11th instant, I beg to state that the Chelsea Company's works were originally laid out for 40,000,000 gallons per diem, and with the works now in action and in progress are calculated to take from the Thames a larger quantity of water than at present, and without materially adding to the present capital the company's works could pump, filter, and deliver into the distributing reservoir 20,000,000 gallons per diem.

I am, &c.,
JAMES SIMPSON.

Wm. Pole, Esq., Secretary,
Royal Commission on Water Supply.

Office of West Middlesex Waterworks,
19, Marylebone Road, W.,

SIR, 19th March 1868.

IN reply to your letter of the 11th instant, inquiring whether the works of the West Middlesex Company are calculated to take from the Thames a larger quantity of water than at present, and if so, what is the maximum daily quantity that we could pump, filter, and deliver into our distributing reservoirs without materially adding to our present capital, and stating also that any further outlay for increased storage and distribution need not be considered, I am desired to inform you that the company is authorized

to take 20,000,000 gallons dailyfrom the Thames, and that our present works at Hampton can, without any increase of capital, pump about 12,000,000 gallons per day. The filter beds at Barnes will yield about 16,000,000 gallons per day, and the engines at Hammersmith will deliver into the district and distributing reservoirs about 14,500,000 gallons per day.

I am desired to add that the average daily supply of the company is about 8,500,000 gallons, and that the present works are considered to be sufficiently ahead of all existing demands.

I am, &c.,
W. H. Whiffin,
Secretary.

To the Secretary, &c.,
Royal Commission on Water Supply,
Committee Room F., House of Lords.

Sumner St., Southwark,
20th March 1688.

Sir,

In reply to your letter of the 11th inst., I beg to inform you that the Grand Junction Water Company have power to take 20,000,000 gallons of water per day into their reservoirs at Hampton, in accordance with their arrangements with the Thames Conservancy Board.

The maximum quantity that could be delivered through the 33-inch main to the works of distribution at Kew Bridge is 13,000,000 gallons in 24 hours.

The reservoirs, filtering beds, and engine power at the Kew Bridge and Campden Hill Works are capable of filtering and delivering this quantity (13,000,000 gallons) to the district in 24 hours.

Reserve engine power, filtering beds, &c. are provided in case of accident, for repairs, cleansing, &c.

The Company have also recently purchased land at Campden Hill, on which it is intended to construct additional works to meet the increasing requirements of their district, and to prevent the present works being tasked beyond their safe working power. The estimated outlay for this and some additions to the Kew Bridge and Hampton Works will amount to at least 140,000*l*.

I am, &c.,
Joseph Quick.

Dr. Pole, &c.,
Royal Commission on Water Supply.

Office of Lambeth Water Works,
175, Kennington Park Road, S.
25th March, 1868.

Sir,

Your letter of the 11th inst., addressed to Mr. Simpson, the Company's engineer, having been laid before the directors of Lambeth Water Works, I am desired by them in reply to acquaint you, for the information of the Royal Commission on Water Supply, that the works of this Company are calculated to take from the River Thames, filter, pump, and deliver the same into the distributary reservoirs, 20,000,000 gallons of water per diem, without materially adding to the present capital.

And I am to state that the works as originally designed were calculated for 40,000,000 per diem, and the land as a pipe track for four large mains to supply that quantity of water was purchased for that purpose soon after the Company's Act of Parliament was obtained.

I am, &c.,
W. S. Phipps,
Secretary.

William Pole, Esq.
Secretary.

Sumner Street, Southwark,
20th March, 1868.

Sir,

In reply to your letter of the 11th inst. I beg to inform you that the Southwark and Vauxhall Water Company have power to take 20,000,000 gallons of water per day into their reservoirs at Hampton in accordance with their arrangements with the Thames Conservancy Board.

The maximum quantity that could be delivered through the 36-inch main to the works of distribution at Battersea is 15,000,000 gallons in 24 hours.

The reservoirs, filtering beds, and engine power at the Battersea works are capable of filtering and delivering this quantity (15,000,000 gallons) to the district in 24 hours.

Reserve engine power, filters, &c., are provided in case of accident, for repairs, cleansing &c.

The Company have also purchased land, and are constructing additional works at Hampton, and laying down a new line of 30-inch main to supply the Western portion of this district. The outlay for this and some additions required to the Battersea works will amount to at least 150,000*l*.

I am, &c.,
Joseph Quick.

Dr. Pole, &c., &c.
Royal Commission on Water Supply.

APPENDIX M.

DETAILS furnished by Mr. BATEMAN in illustration of his EVIDENCE.

No. 1. PARTICULARS of ESTIMATE of Mr. BATEMAN'S Scheme for obtaining a Supply of Water from NORTH WALES of 230,000,000 gallons daily.—Revised December 1867.

RESERVOIRS and WORKS of COLLECTION and BRANCH AQUEDUCTS to MARTEN MERE.

Rivers Vyrnwy and Banw District.

Vyrnwy District.			
Reservoir at Llanwddyn:—			
Embankment 76 ft. high, capacity, with 70 feet depth of water at embankment, 1,490,000,000 cubic feet:—			
Earthwork 186,000 cubic yards, at 1*s.* 6*d.*	£13,950		
Tunnel, discharge pipes, and valves, 150 lineal yards, at 50*l.*	7,500		
Waste weir, valve houses, &c.	5,000		
Fencing 10 miles at 200*l.* per mile	2,000		
	£28,450		
Diversion of roads, to include bridges, culverts, drains, fencing, &c.:—			
Six miles at 2,200*l.* per mile	£13,200		
Three miles at 880*l.* per mile	2,640		
	15,840		
		£44,290	
Diversion of flood water of the Afon Conwy to Llanwddyn reservoir.—Drainage area, 3,016 acres.			
Open watercourse, 2,200 lineal yards at 2*l.*	£4,400		
Tunnel, 1,320 lineal yards at 10*l.*	13,200		
	17,600		
			£61,890
Diversion of the river Vyrnwy at Pont Hagel to reservoir at Rhyd e Gro.			
Flood waters from 10,879 acres to be diverted, quantity provided for, 2,000 cubic feet per second.			
Weir across river Vyrnwy at point of diversion	£7,000		
Open watercourse (for detailed estimate and section, see Appendix A Q (1) 3,740 lineal yards at 11*l.*	£41,140		
Bridges, drains, &c.	3,000		
	44,140		
Tunnel (for detailed estimate and section, see Appendix A Q (2) 1,100 lineal yards, at 22*l.*	24,200		
		75,340	
			£137,230
Banw District.			
Reservoir at Can office. Embankment 80 feet high. Capacity, with 75 feet depth of water at embankment, 767,171,800 cubic feet.			
Earthwork, 300,000 cubic yards at 1*s.* 6*d.*	£22,500		
Discharge tunnel, pipes, valves, 150 lineal yards at 50*l.*	7,500		
Waste weir and valve houses	3,000		
Fencing six miles, at 200*l.*	1,200		
	£34,200		
Amount carried forward		£34,200	

Reservoirs and Works of Collection, &c.—*continued.*			
Rivers Vyrnwy and Banw District—*continued.*			
Banw District—*continued.*			
Amount brought forward		£34,200	
Diversion of roads, including bridges, culverts, drains, fencing, &c.			
3½ miles at 2,500*l.* per mile	£8,750		
2 miles at 1,320*l.* per mile	2,640		
	£11,390		
		£45,590	
Reservoir at Rhyd e Gro. Embankment 80 feet high. Capacity, with 75 feet depth of water at embankment, 974,636,900 cubic feet.			
Earthwork, 406,000 cubic yards, at 1*s.* 6*d.*	£30,450		
Discharge tunnel, pipes, valves, &c., 150 lineal yards, at 50*l.*	7,500		
Waste weir, valve houses, &c.	5,000		
Fencing, 7 miles, at 200*l.*	1,400		
	£43,350		
Road diversions, including bridges, culverts, drains, fencing, &c., 1 mile at 2,500*l.* £2,500			
3 miles at 1,320*l.* 3.960	6,460		
		£49,810	
Reservoir at Nant y eira. Embankment 80 feet high. Capacity, with 75 feet depth of water at embankment, 261,360,000 cubic feet.			
Earthwork, 97,000 cubic yards, at 2*s.*	£9,700		
Discharge tunnel, pipes, valves, &c.	4,000		
Waste weir, valve houses, &c.	4,000		
Fencing, 3½ miles at 200*l.*	700		
	£18,400		
Road diversions, odd prices	1,000		
		£19,400	
Flood watercourse from the upper end of the Nant y eira reservoir to the Can office reservoir to take surplus water; 3 miles, at 7,040*l.* per mile, including bridges, culverts, &c.	21,120		
		£135,920	
			£273,150
Branch aqueduct from Rhyd e Gro to Marten Mere. Open watercourse (for detailed estimate and section, see Appendix A Q (3); 5 miles, at 20,100*l.* per mile		100,500	
Covered watercourse, or tunnel (for detailed estimate and section, see Appendix A Q (4); 12 miles, at 26,100*l.* per mile		313,200	
Syphon across the valley of the Severn near Berriew (for detailed estimate, see Appendix A Q (5): 5 lines of 4 feet pipes; 2 miles, at 54,120*l.* per mile	£108,240		
Valves, wells, and crossing of river	5,000		
		113,240	
			526,940
Amount carried forward			£800,090

Reservoirs and Works of Collection, &c.—*continued.*

Rivers Vyrnwy and Banw District—*continued.*

Amount brought forward -		800,090
Banw District—*continued.*		
Amount brought forward - - -		
Contingencies:—15 per cent. on all works, except piping -	£686,850 =	103,027
5 per cent. on piping -	113,240 =	5,662
		108,689
Land for reservoirs, watercourses, and aqueducts, including rebuilding of church and village, and compensation - - - -		180,240
Total cost of Vyrnwy and Banw district branch of scheme, down to junction with main aqueduct at Marten Mere, capable of supplying to the city 130,000,000 gallons daily - - - - - - - -		£1,089,019

River Severn proper District.

Reservoir on the river Clwyedog. Embankment 70 feet high; capacity, with 65 feet depth of water at embankment, 203,056,522 cubic feet.			
Earthwork, 144,000 cubic yards, at 1*s.* 6*d.* - - -	£10,800		
Discharge tunnel, pipes, valves, &c., 130 lineal yards, at 40*l.* - -	5,200		
Waste weir, valve houses, &c. - - - -	2,500		
Fencing, 4½ miles, at 200*l.*	900		
	£18,400		
Diversion of roads, including bridges, culverts, drains, fencing, &c., 1 mile at 2,500*l.*	£2,500		
1½ mile at 880*l.*	1,320	3,820	
			£22,220
Reservoirs on the river Dulas and other streams south of the Severn; sites not surveyed; capacity required, 216,807,000 cubic feet. Estimate assumed to be the same as for the reservoir and accessory works on the river Clwyedog, £22,220 say - - - - -			25,000
Reservoir at Trefeglws on the rivers Ceryst and Tarannon.—Embankment 76 feet high; capacity, with 70 feet depth of water at embankment, 2,794,717,000 cubic feet.			
Earthwork, 1,620,000 cubic yards, at 1*s.* 2*d.*	£94,500		
Discharge tunnels, pipes, valves, &c., 300 lineal yards, at 50*l.* - -	15,000		
Waste weir, valve houses, &c. - - - -	6,000		
Fencing, 14 miles at 200*l.*	2,800		
Diversion of roads, including bridges, culverts, drains, fencing, &c., 3½ miles at 2,500*l.*	£8,750		
3 miles at 1,320*l.*	3,960		
		12,710	
			131,010
			£178,230
Diversion of streams. Tunnel from river Clwyedog to river Ceryst to convey water from Clwyedog reservoir and flood water of the river below to the point of diversion to the reservoir at Trefeglws. Quantity provided for, 1,500 cubic feet per second (for detailed section and estimate, see Appendix A Q (6); 1,320 lineal yards at 20*l.* - - -			£26,400
Amounts carried forward			

Reservoirs and Works of Collection, &c.—*continued.* No. 1.

River Severn proper District—*continued.*

Amount brought forward - -			
Reservoir at Trefeglws—*continued.*			
Amount brought forward - - -			
Watercourse to convey water from reservoirs on the Dulas and other streams and flood waters of said streams to the reservoir at Trefeglws. Quantity provided for, 2,000 cubic feet per second. Open watercourse, 3,520 lineal yards, at 6*l.* per lineal yard - -	£21,120		
Culverts, bridges, &c.	2,000		
	£23,120		
Tunnel (for detailed estimate and section, see Appendix A Q (2); 1,650 lineal yards at 22*l.* -	36,300		
Weirs on streams whence water is diverted—three	3,000		
		62,420	
Watercourse to convey the flood water of the river Carno. Drainage area, 17,289 acres; quantity provided for, 3,500 cubic feet per second.			
Weir on river Carno at point of diversion - - -	£1,000		
Open watercourse 740 lineal yards, at 9*l.* per lineal yard -	£63,360		
Culverts, bridges, &c. - -	6,000		
	£69,360		
		£70,360	
			159,180
			£337,410
Aqueduct from Trefeglws to Marten Mere, to convey 100,000,000 gallons per day.			
Open watercourse (for detailed estimate and section, see Appendix A Q (7), 14½ miles at 14,820*l.* per mile - - - - -		£214,890	
Tunnel or covered watercourse (for detailed estimate and section, see Appendix A Q (8), 7 miles, at 24,000*l.* per mile - - -		168,000	
Additional, for three crossings of the river Severn - - -		30,000	
			412,890
			£750,300
Contingencies, 15 per cent. - - - -			112,558
Land for reservoirs, watercourses, and aqueduct, and including rebuilding of church and village, and compensation - - -			199,550
Total cost of *Severn proper district branch* of scheme down to junction with main aqueduct at Marten Mere, capable of supplying to the city 100,000,000 gallons daily -			£1,062,408

Main Aqueduct, from Marten Mere to Service Reservoirs near Stanmore.

Syphons equal to the conveyance of 130,000,000 gallons daily.

	Aqueduct.	
Open (for detailed estimate and section, see Appendix A Q (9), 75½ miles, at 25,000*l.* per mile	£1,887,500	
Covered or tunnel (for detailed estimate and section, see Appendix A Q (10), 65 miles, at 33,180*l.* per mile - - -	2,156,700	
Syphons across the river Severn at Bridgenorth, the river Stour, and the river Avon. Five lines of 4 feet pipes, 11½ miles, at 54,120*l.* per mile -	£622,380	
Valves and three river crossings, &c. - -	10,000	
		632,380
		£4,676,580

No. 1. Main Aqueduct from Martin Mere—*continued.*

Amount brought forward -		£4,676,580
Contingencies. 15 per cent. on all works except piping, 4,044,200*l.* - -	606,630	
5 per cent. on piping, 633,380*l.* - -	31,669	
	638,299	
		5,314,879
Land - - - - - - - - -		138,480
		£5,453,359

Estimate for Service Reservoirs at Edgware or Stanmore, and for Aqueduct and Main Pipes to communicate with existing Distribution Arrangement for the first instalment of 130,000,000 gallons per day.

Service reservoirs at Edgware, including land and contingencies, see p. 3. - - -		£237,438
District No. 1.		
Aqueduct to Hornsey, see p. 3. -	£104,864	
Mains to New River and East London districts, see p. 4. - -	70,270	
		175,134
District No. 2. Mains, see p. 4. - - -		118,650
District No. 3. Mains and bridge over the Thames, see p. 4. - - - - -		240,838
District No. 4. Mains, see p. 4. - - -		162,750
Additional service reservoirs in several districts.	Gallons.	
District No. 1. East London -	10,000,000	
„ „ 2. None required.		
„ „ 3. Kent- - -	5,000,000	
„ „ „ Lambeth and Southwark and Vauxhall -	5,000,000	
„ „ 4. Present reservoirs on Putney Heath to be enlarged -	5,000,000	
	25,000,000	
25,000,000 gallons at 5,000*l.* per 1,000,000 -		125,000
		£1,059,810

Particulars of Estimate of cost of service reservoirs at Edgware, and of aqueduct and main pipes to communicate with existing distribution arrangements.

Service Reservoirs, two in number. Greatest height of embankments, 66 ft. and 68 ft. Slopes 3 to 1 inside, and 2 to 1 outside. Capacity, 2,771,733,298 gallons.

Earthwork, 1,687,712 cubic yards, say 1,700,000 cubic yards, at 1*s.* 3*d.* - -	£106,250
Beaching slopes - - - - - -	20,000
Waste weirs, strainers, pipes, &c. - -	15,000
	£141,250
Contingencies, 15 per cent. - - - -	21,188
Land - - - - - - - -	75,000
	£237,438

TABLE A.

Table showing the probable Proportion of the first Instalment of 130,000,000 gallons per day required by each Company's District.

—	Present supply (1866).	Proportionate addition.	Estimated requirements in 1875 or 1876.
New River - -	23,000,000	5,600,000	28,600,000
East London -	19,300,000	7,300,000	26,600,000
Chelsea - -	8,000,000	1,150,000	9,150,000
West Middlesex -	8,250,000	4,350,000	12,600,000
Grand Junction -	8,700,000	4,600,000	13,300,000
Southwark and Vauxhall.	12,700,000	6,700,000	19,400,000
Lambeth - -	9,000,000	2,250,000	11,250,000
Kent - -	6,050,000	3,050,000	9,100,000
	95,000,000	35,000,000	130,000,000

It is proposed to form the metropolis into four districts, each communicating independently with the reservoirs at Edgware. These districts are,—

	Gallons daily.
No. 1. New River, supply required - -	28,600,000
East London, „ „ - -	26,600,000
	55,200,000
No. 2. Chelsea, supply required -	9,150,000
West Middlesex, „ „ -	12,600,000
Grand Junction „ „ -	13,300,000
	35,050,000
No. 3. Higher parts of the Lambeth and Southwark and Vauxhall districts, supply required, estimated at - - -	10,000,000
Kent district, supply required - -	9,100,000
	19,100,000
No. 4. Lower parts of the Lambeth and Southwark and Vauxhall districts - -	20,650,000

Level of top water of proposed service reservoirs near Edgware will be 270 feet above ordnance datum, or 257½ feet above Trinity high-water mark.

District No. 1.

The water will be conveyed to this district by a covered aqueduct commencing at the service reservoirs, at the level of 250 feet above ordnance datum at least, and terminating near Crouch End. From the end of the aqueduct the water will be conveyed by main pipes to the Maiden Lane reservoirs of the New River Company for their district, and to the new Hornsey reservoir and Lea Bridge for the supply of the East London district.

Aqueduct will be of the same size as the Loch Katrine aqueduct, with a fall of 14 inches per mile; the discharge will be as follows:—

Area, 49·317 square feet; wetted sides, 20·65 feet; mean velocity, 2·15 feet per second; discharge, 57,088,000 gallons per day.

Length of aqueduct, 7 miles, at 7*l.* per lineal yard - - - - - - - - -	£86,240
(This estimate is the average amount paid for the Duntreath section of the Loch Katrine aqueduct, which included 4 tunnels and 8 aqueducts, besides stream crossings, drains, &c. The amount of the final certificate, including all extras, was 61,769*l.*, and the length of the aqueduct was 8,888 lineal yards, or rather less than 7*l.* per lineal yard.)	
Contingencies, 10 per cent. - - - -	8,624
Land - - - - - - - - -	10,000
	£104,864

Level of aqueduct at the commencement, 250 feet above ordnance datum.

Level of ditto at its termination, 7 miles, at 14 inches fall per mile, 241 feet 10 inches above ditto.

Level of Maiden Lane reservoirs, 231 ft. 6 in. above ditto.

Level of New Hornsey reservoir, 140 ft. above ditto.

Level of Lea Bridge works, about 20 ft. above ditto.

	Distance.
Fall from termination of aqueduct to Maiden Lane, 10 ft. 4 in. - - - - - -	1½ mile.
Fall from ditto to New Hornsey reservoir, 101 ft. 10 in. - - - - - - -	1½ mile.
Fall from ditto to Lea Bridge, 221 ft. 10 in. -	4½ miles.

	Gallons per day.
Quantity to be delivered into Maiden Lane reservoir for New River district - -	28,600,000
Quantity to be delivered into New Hornsey reservoir, or to existing mains at Lea Bridge	26,600,000
New River supply.	
4 ft. pipe, with 7 ft. fall per mile, will deliver, according to calculation - - - -	23,516,000
Add 25 per cent. for actual over theoretical discharge - - - - - - -	5,879,000
Total -	29,095,000

No. 1.

East London supply. 4 ft. pipe with 7 ft. fall per mile, will deliver same quantity into New Hornsey reservoirs, or into existing mains at Lea Bridge, with a pressure at the latter place of about 190 feet.

Estimate:—One 4 ft. pipe to Maiden Lane reservoirs, 1½ miles in length; thickness, 1 in.; weight per yard, 14½ cwt. at 6*l.* per ton	14½ cwt. £4 7	
Laying and jointing	0 15	
Per lineal yard	£5 2	
2,640 lineal yards at 5*l.* 2*s.*		£13,464
1 4 ft. pipe to New Hornsey reservoir, and thence to Lea Bridge. Length, 4½ miles; thickness, 1⅜ in. on the average; weight per lineal yard, 20 cwt.	20 cwt. at 6*l.* per ton £6 0	
Laying and jointing	0 15	
	£6 15	
7,920 lineal yards at 6*l.* 15*s.*		53,460
		£66,924
Contingencies. 5 per cent. on piping		3,346
		£70,270

The existing service reservoirs of the New River Company will be sufficient for their district.

For the East London district it will be desirable to add to their new service reservoir at Hornsey, or construct others to hold half a day's supply, or about 14,000,000 gallons. The estimated capacity of the new Hornsey reservoir is 4,500,000 gallons; deficiency, 9,500,000 gallons — say 10,000,000 gallons.

District No. 2.

The water will be conveyed to this district by a 4 ft. pipe from the service reservoirs at Edgware, which will communicate with the West Middlesex main from Campden Hill to Barrow Hill, and be continued into the Grand Junction district to join their high district main, and so to the reservoirs on Campden Hill. From these reservoirs a main of 3 ft. diameter will be laid to communicate with the leading mains of the Chelsea district.

Pipe will leave reservoirs under pressure from a height of 270 feet above ordnance datum when the reservoir is full; but assume for calculations 262 feet 6 inches above ordnance datum (or 250 feet above Trinity high-water mark).

Existing Service Reservoirs.	Elevation above ordnance datum.	Capacity, gallons.
Notting Hill, West Middlesex	124 ft. 6 in.	3,672,000
Campden Hill, Grand Junction	132 ft. 6 in.	6,000,000
Barrow Hill, West Middlesex	190 ft.	4,750,000
Kidderpore do.	321 ft. 6 in.	2,500,000
		16,922,000

Quantity required for the whole district, 35,050,000 gallons daily.

Difference in level between reservoirs at Stanmore and mean elevation of reservoirs at Campden Hill and Barrow Hill (say 160 feet above ordnance datum on average), 262′ 6″—160″=102½ feet.

Distance from Edgware to Campden Hill, 10½ miles.

Fall equal about 9¾ feet per mile.

	Gallons.
4 ft. pipe, fall 9¾ feet per mile, will discharge	28,250,000
Add 25 per cent. for actual over theoretical discharge	7,062,500
	35,312,500

Estimate.

One 4 ft. main from Edgware to point of intersection with main from Campden Hill to Barrow Hill, 8½ miles, and thence to communicate with high-service main of Grand Junction district, 1½ miles; total 10 miles, at 10,000*l.* per mile		£100,000
One 3 ft. main from Campden Hill reservoir to intersect main lines of pipes to Chelsea district; 2 miles at 6,500*l.* per mile		13,000
		£113,000
Contingencies, 5 per cent.		5,650
		£118,650

District No. 3.

The water will be conveyed to this district by a 4 ft. main, crossing the Thames near Vauxhall Bridge by a special aqueduct; the 4 ft. pipe will then branch into two 36 in. pipes—one to the Streatham reservoir of the Lambeth Company, for the supply of the higher parts of that and the Southwark and Vauxhall Company's district; the other to new reservoirs to be made in or near Greenwich Park or Blackheath.

Service reservoir at Streatham Hill, 197 feet 6 inches above ordnance datum, to be enlarged so as to hold 5,000,000 gallons.

Distance from Edgware reservoirs to Streatham, 16 miles.

Service reservoir to be constructed at Greenwich at a level of about 160 feet ordnance datum, and to have a capacity of about 5,000,000 gallons.

Distance from Edgware reservoirs to Blackheath, 17½ miles.

Quantity required for—

	Gallons daily
Kent district	9,100,000
Lambeth high districts	5,000,000
Southwark and Vauxhall ditto	5,000,000
	10,000,000

Distance from Edgware reservoirs to south side of Vauxhall Bridge, 12 miles.

Difference of level between Edgware and—

Streatham, 262 ft. 6 in.:—197 ft. 6 in. = 65 ft., or 4 ft. fall per mile.

Blackheath, 262 ft. 6 in.:—160 ft.=102 ft. 6 in., or 6 ft. fall per mile.

	Gallons daily.
3 ft. pipe to Streatham, with 4 ft. fall per mile, will deliver	8,351,000
Add 25 per cent. for actual over theoretical discharge	2,087,750
	10,438,750
3 ft. pipe to Blackheath; fall 6 feet per mile	10,470,000
Add 25 per cent., as above	2,617,500
	13,087,500
Total capability of 3 ft. pipes	23,526,250

Estimate:—4-ft. pipe from Edgware to south side of Vauxhall Bridge, 12 miles, at 10,000*l.* per mile		£120,000
3 ft. pipe to Streatham, 4 miles, at 6,500*l.*		26,000
3 ft. pipe to Blackheath, 5½ miles, at 6,500*l.*		35,750
		181,750
Contingencies, 5 per cent.		9,088
		190,838
Bridge over Thames, near Vauxhall Bridge, to carry three lines of 4 feet pipes		50,000
		£240,838

District No. 4.

It is proposed to lay down a 48-in. main from Edgware to the existing service reservoirs at Putney Heath of the Chelsea Water Company, and to use them for distributing to the lower districts of the Lambeth and Southwark and Vauxhall Companies.

The elevation of the reservoirs at Putney is 172 ft. 6 in. above ordnance datum.

The distance from Edgware is 15½ miles, and the difference of level is 90 feet, or nearly 6 feet fall per mile.

	Gallons daily.
One 4 ft. pipe with 6 ft. fall per mile will deliver	21,653,000
Add 25 per cent. for actual over theoretical discharge	5,413,250
	27,066,250
Quantity required for this district	20,650,000

Estimate:—15½ miles of 4 ft. pipes, at 10,000*l.* per mile		£155,000
Contingencies, 5 per cent.		7,750
		£162,750

No. 1.

WELSH SCHEME.—2nd Instalment.

Estimate of additional outlay required to increase the supply to 170,000,000 gallons daily, and of the cost to be incurred in distributing the additional quantity (40,000,000) to the several districts of supply.

Works in Wales and on main aqueduct to Edgware.

Reservoirs and works of collection of the river Severn proper branch of the scheme, and branch aqueduct to Marten Mere, as per estimate, see p. 2.		£1,062,408
Syphons. Two additional lines of 4 ft. pipes on line of main aqueduct to Edgware, 11½ miles, at 21,648*l.*	£248,952	
Valves and river crossings (3)	5,000	
	£253,952	
Contingencies, 5 per cent.	12,698	
		266,650
		1,329,058
Additional service reservoir at Edgware, and works for distributing additional quantity of 40,000,000 gallons daily, (for particulars, see pp. 5 and 6.)		557,551
		£1,886,609

TABLE showing the probable Proportion of the whole Supply, when it amounts to 170,000,000 gallons daily, required by each Company's District.

	First Instalment.	2nd Instalment of 40,000,000 gallons additional.	Total.
New River Co. -	28,600,000	8,580,000	37,180,000
East London -	26,600,000	7,980,000	34,580,000
Chelsea - -	9,150,000	2,835,000	11,985,000
West Middlesex -	12,600,000	3,780,000	16,380,000
Grand Junction -	13,300,000	3,990,000	17,290,000
Southwark and Vauxhall.	19,400,000	5,820,000	25,220,000
Lambeth - -	11,250,000	3,375,000	14,625,000
Kent - -	9,100,000	3,640,000	12,740,000
	130,000,000	40,000,000	170,000,000

		Gallons.	Gallons.
District No. 1.	New River -	37,180,000	
	East London	34,580,000	
			71,760,000
District No. 2.	Chelsea - -	11,985,000	
	West Middlesex -	16,380,000	
	Grand Junction -	17,290,000	
			45,655,000
„ „ 3.	Higher parts of Lambeth district - -	8,000,000	
	Southwark and Vauxhall -	8,000,000	
		16,000,000	
	Kent - - -	12,740,000	
			28,740,000
„ „ 4.	Lower parts of Lambeth district - -	6,625,000	
	Southwark and Vauxhall -	17,220,000	
			23,845,000
			170,000,000

District No. 1.

Total supply - - -	71,760,000	gallons daily.
Supply under 1st instalment -	55,200,000	„ „
Additional quantity - -	16,560,000	„ „

It will be necessary to make another aqueduct from the reservoirs at Edgware to near Crouch End, and lay an additional pipe from thence to the New River reservoirs at Maiden Lane for the additional quantity required for that district, viz., 8,580,000 gallons daily.

The 4-ft. pipe to the proposed service reservoirs of the East London district, and to the Lea Bridge mains, provided for the distribution of the 1st instalment, will deliver the additional quantity of 7,980,000 gallons required for this district, with an extra fall of 3 feet per mile, reducing the effective pressure at Lea Bridge from 190 feet to about 175 feet.

Additional service reservoirs, to the extent of about 4,000,000 gallons, will be required for the East London district.

Estimate.

Aqueduct from Edgware to Crouch End, same dimensions, as before - - -		£104,864
1 4-ft. pipe to Maiden Lane reservoirs - - - - -	£13,464	
5 per cent. for contingencies - -	673	
		14,137
		£119,001

District No. 2.

Total supply - - -	45,655,000	gallons daily.
Supply under 1st instalment -	35,050,000	„ „
Additional quantity - -	10,605,000	„ „

It will be necessary to lay an additional main from Edgware for the supply of this district, and looking to future wants, it would be well to provide for an additional 4-ft. pipe all the way through the higher parts of the Paddington district to Campden Hill, a distance of 10½ miles. The actual discharge of this pipe, with a fall of 12½ feet per mile, will be, at the level of Campden Hill, 132½ feet above ordnance datum, about 40,000,000 gallons in 24 hours.

Additional service reservoirs, to the extent of about 6,000,000 gallons, will also be required in this district.

Estimate.

One 4-ft. pipe from Edgware to Campden Hill, 10½ miles at 1,000*l.* per mile - - -	£105,000
Contingencies, per cent. - - - -	5,250
	£110,250

District No. 3.

Total quantity required,	28,740,000	gallons daily.
Supply under 1st instalment,	19,100,000	„ „
Additional supply	9,640,000	gallons daily.

Of this additional quantity, 3,640,000 gallons are for the Kent district, and 6,000,000 for the higher parts of the Lambeth and Vauxhall districts.

The pipe provided for the 1st instalment to the Kent districts will be sufficient to deliver the whole quantity now estimated to be there required, viz., 12,740,000 gallons per day.

For the higher parts of the Lambeth and Southwark and Vauxhall districts it will be necessary to lay additional pipes, and looking to the future requirements of the district it is desirable to lay a new 4-ft. main from Edgware to the south side of Vauxhall Bridge, and a 3-foot pipe thence to the proposed service reservoirs at Streatham.

Additional service reservoirs for the Kent and higher parts of the Lambeth and Southwark and Vauxhall districts will be required to the extent of 5,000,000 gallons.

Estimate.

One 4-ft. pipe from Edgware to south side of Vauxhall Bridge, 12 miles at 10,000*l.* per mile - - - - - - - -	£120,000
1 3-ft. pipe from thence to Streatham, 4 miles, at 6,500*l.* - - - - - - -	26,000
	£146,000
Contingencies, 5 per cent. - -	7,300
	£153,300

No. 1. Welsh Scheme—2nd Instalment—*continued.*

No. 4 District.

Total supply - - -	23,845,000 gallons daily.
Supply under 1st instalment	20,650,000 „ „
Additional quantity	3,195,000

The 4-ft pipe laid down for the first instalment will be sufficient for the additional quantity.

Summary of estimate for additional reservoir at Edgware, and for additional aqueduct and main pipes to communicate with existing distribution arrangements for delivering a total supply of 170,000,000 gallons per day.

Service reservoir at Edgware, including land and contingencies, say - - - -	£100,000
District No. 1—Aqueduct to Hornsey and main to Maiden Lane reservoirs - -	119,000
District No. 2. Mains - - - -	110,250
District No. 3. Mains - - - -	153,300
District No. 4. Nil.	
Additional service reservoirs in several districts.	
No. 1. East London - - 4,000,000 gallons	
„ 2. - - - - 6,000,000 „	
„ 3. - - - - 5,000,000 „	
15,000,000 gallons.	
15,000,000 gallons at 5,000*l.* per million.	75,000
	£557,551

Welsh Scheme.—3rd Instalment.

Estimate of cost to be incurred to increase the supply to 200,000,000 gallons daily, and for distributing the additional supply of 30,000,000 gallons daily to the several districts.

Syphons on line of main aqueduct to Edgware, 1 line of 4-ft. pipes. 11½ miles at 10,824*l.* - - - - -	£124,476	
Valves and river crossings (3)	2,500	
	£126,976	
Contingencies, 5 per cent - -	6,348	
		£133,324
Additional mains for distribution and district service reservoir (see pages 6 and 7) - -		117,535
		£250,859

Table showing the probable Proportion of the whole Supply, when it amounts to 200,000,000 gallons daily, required by each Company's District.

	First and Second Instalments.	3rd Instalment, 30,000,000 additional.	Total.
	Gallons.	Gallons.	Gallons.
New River - -	37,180,000	6,500,000	43,680,000
East London -	34,580,000	6,000,000	40,580,000
Chelsea - -	11,985,000	1,500,000	13,485,000
Grand Junction -	17,290,000	3,000,000	20,290,000
West Middlesex -	16,380,000	3,000,000	19,380,000
Southwark and Vauxhall -	25,220,000	4,000,000	29,220,000
Lambeth - -	14,625,000	2,500,000	17,125,000
Kent - -	12,740,000	3,500,000	16,240,000
	170,000,000	30,000,000	200,000,000

		Gallons.	Gallons.
District No. 1.	New River -	43,680,000	
	East London -	40,580,000	
			84,260,000
„ 2.	Chelsea - -	13,854,000	
	Grand Junction -	20,290,000	
	West Middlesex -	19,380,000	
			53,155,000
Carried forward - -			137,415,000

Welsh Scheme.—3rd Instalment—*continued.* No. 1

			Gallons.
Brought forward - - -			137,415,000
District No. 3.	Higher parts of Lambeth district	10,500,000	
	Southwark and Vauxhall - -	10,000,000	
		20,500,000	
	Kent - -	16,240,000	
			36,740,000
„ 4.	Lower parts of Lambeth district	6,625,000	
	Southwark and Vauxhall - -	19,220,000	
			25,845,000
			200,000,000

District No. 1.

	Gallons daily.
Total supply - - - - - - -	84,260,000
Supply under 1st and 2nd instalments -	71,760,000
Additional quantity - - - -	12,500,000

The aqueducts already provided for will deliver more than the total quantity required, and the pipes to Maiden Lane reservoirs will supply more than the additional quantity required for the New River district.

The 4-ft. pipe to the proposed service reservoirs of the East London district and to Lea Bridge, already provided for in the estimates, will deliver the additional quantity of 6,000,000 gallons required for this district, with an extra fall of 3 feet per mile, reducing the effective pressure at Lea Bridge to about 160 feet.

No additional outlay will be required for this district, except for service reservoirs to the extent of 6,000,000 gallons.

District No. 2.

	Gallons daily.
Total supply - - - - - -	53,155,000
Supply under 1st and 2nd instalments - -	45,655,000
Additional quantity - - - - -	7,500,000

The mains already estimated for for this district are much more than equal to the delivery of the additional supply. No outlay is consequently necessary for this district, except for additional service reservoirs to the extent of about 4,000,000 gallons.

District No. 3.

Total supply - - - - - - -	36,740,000
Supply under 1st and 2nd instalments - -	28,740,000
Additional quantity - - - - -	8,000,000

3,500,000 gallons additional are for the Kent district, and 4,500,000 gallons for the higher parts of the Lambeth and Southwark and Vauxhall districts.

The 4-ft. mains to be laid from Edgware to the south side of Vauxhall Bridge, already estimated for, are more than sufficient for the whole district, but an additional 3-ft. pipe will be required for the Kent district. The pipes to the Streatham proposed service reservoirs are equal to the additional supply.

Additional service reservoirs to the extent (4,000,000) gallons will be required for the district.

Estimate.

5½ miles of 3-ft. pipe to Blackheath, at 6,500*l.* per mile - - - - - - - -	£35,750
Contingencies, 5 per cent. - - - -	1,785
	£37,535

District No. 4.

	Gallons daily.
Total supply - - - - - -	25,845,000
Supply under 1st and 2nd instalments -	23,845,000
Additional supply - - - - -	2,000,000

The main already provided is equal to the delivery of this additional quantity; no outlay is consequently required in this district, except for service reservoirs to the extent of say 2,000,000 gallons.

No. 1. Welsh Scheme—3rd Instalment—*continued.*

Summary of outlay to be incurred in distributing the additional 30,000,000 gallons daily, increasing the total supply to 200,000,000 gallons daily:—

District No. 3—Main	£37,535
Additional service reservoirs:—	
District No. 1 - 6,000,000 gallons.	
„ „ 2 - 4,000,000 „	
„ „ 3 - 4,000,000 „	
„ „ 4 - 2,000,000 „	
16,000,000 gallons.	
16,000,000 gallons, at 5,000*l.* per million -	80,000
	£117,535

Welsh Scheme.—4th Instalment.

Estimate of cost to be incurred to increase the supply to 230,000,000 gallons daily, and for distributing the additional 30,000,000 gallons daily to the several districts:—

Syphon on line of main aqueduct to Edgware, 1 line of 4-ft. pipes, 11½ miles at 10,824*l.*	£124,476	
Valves and river crossings (3)	2,500	
	£126,976	
Contingencies, 5 per cent.	6,348	
		£133,324
Additional service reservoir at Edgware, and mains and district service reservoirs (see page 7)		444,225
		£577,549

Table showing the probable Proportion of the whole Supply, when it amounts to 230,000,000 gallons daily, required in each Company's District.

—	1st, 2nd, and 3rd Instalments.	4th Instalment, 30,000,000 additional.	Total.
	Gallons.	Gallons.	Gallons.
New River	43,680,000	6,500,000	50,180,000
East London	40,580,000	6,000,000	46,580,000
Chelsea	13,485,000	1,500,000	14,985,000
Grand Junction	20,290,000	3,000,000	23,290,000
West Middlesex	19,380,000	3,000,000	22,380,000
Southwark and Vauxhall	29,220,000	4,500,000	33,720,000
Lambeth	17,125,000	2,500,000	19,625,000
Kent	16,240,000	3,000,000	19,240,000
	200,000,000	30,000,000	230,000,000

		Gallons daily.	Total.
District No. 1.	New River	50,180,000	
	East London	46,580,000	
			96,760,000
„ „ 2.	Chelsea	14,985,000	
	Grand Junction	23,290,000	
	West Middlesex	22,380,000	
			60,655,000
„ „ 3.	Higher parts of Lambeth	12,000,000	
	Southwark and Vauxhall	12,500,000	
		24,500,000	
	Kent	19,240,000	
			43,740,000
„ „ 4.	Lower parts of Lambeth	7,625,000	
	Southwark and Vauxhall	21,220,000	
			28,845,000
			230,000,000

District No. 1.

	Gallons daily.
Total supply	96,760,000
Supply under 1st, 2nd and 3rd instalments	84,260,000
Additional quantity	12,500,000

Welsh Scheme—4th Instalment—*continued.*

The aqueducts and mains already provided for this district are equal to the supply of the additional quantity, but the effective pressure at Lea Bridge will be reduced to about 150 feet. No outlay is required for this district except for additional service reservoirs to the extent of 6,500,000 gallons.

District No. 2.

	Gallons daily.
Total supply	60,655,000
Supply under previous instalments	53,155,000
Additional supply	7,500,000

The mains provided for this district are more than sufficient for the additional supply, but new service reservoirs, to the extent of 3,500,000 gallons, will be required.

District No. 3.

	Gallons daily.
Total supply	43,740,000
Supply under previous instalments	36,740,000
Additional quantity	7,000,000

Of which 3,000,000 are for the Kent district, and 4,000,000 for the higher parts of the Lambeth and Southwark and Vauxhall districts.

The mains already laid to the Kent district are more than sufficient for the delivery of the new supply.

For the higher parts of the Lambeth and Vauxhall an additional main from Edgware will be necessary, and additional service reservoirs to the extent of 3,500,000 gallons will be required for the whole district.

Estimate:—

4-feet pipe from Edgware to south side of Vauxhall Bridge, 12 miles, at 10,000*l.* per mile	£120,000
3-feet pipe to Streatham, 4 miles, at 6,500*l.* per mile	26,000
	£146,000
Contingencies, 5 per cent.	7,300
	£153,300

District No. 4.

	Gallons daily.
Total supply	28,845,000
Supply under previous instalments	25,845,000
Additional supply	3,000,000

It will be necessary to lay an additional main from Edgware to the reservoirs on Putney Heath, say 3 feet diameter.

3-ft. pipe, 15½ miles, at 7,000*l.* per mile	£108,500
Contingencies, 5 per cent.	5,425
	£113,925

Summary of outlay required in distributing the additional 30,000,000 gallons daily, increasing the supply to 230,000,000 gallons daily.

Service reservoir at Edgware, including land and contingencies, say		£100,000
Additional mains:—		
District No. 3	£153,300	
„ „ 4	113,925	
		267,225
Additional district service reservoirs:		
District No. 1 - 6,500,000 gallons		
„ „ 2 - 3,500,000 „		
„ „ 3 - 3,500,000 „		
„ „ 4 - 1,000,000 „		
14,500,000		
say 15,000,000 gallons, at 5,000*l.*		75,000
		£442,225

No. 1. Welsh Scheme—4th Instalment—*continued.*

SUMMARY of estimated cost of works for obtaining a supply of 230,000,000 gallons daily from North Wales, and distributing same to the existing centres of supply.

Reservoirs and works of collection on the rivers Vyrnwy and Banw, and aqueduct to convey 130,000,000 gallons daily to main aqueduct at Marten Mere. (For particulars, see pages 1 and 2.)	£1,089,019
Reservoirs and works of collection in the river Severn proper district, and aqueduct to convey 100,000,000 gallon daily to main aqueduct at Marten Mere. (For particulars, see page 2.)	1,062,408
Main aqueduct from Marten Mere to service reservoirs near Stanmore. Syphons equal to the conveyance of 130,000,000 gallons daily. (For particulars, see pages 2 and 3.)	5,453,359
Additional syphons on line of main aqueduct for the conveyance of 100,000,000 gallons daily in addition, making a total of 230,000,000 gallons daily	533,298
	£8,138,084

Service reservoirs near Stanmore, and works for distributing water to existing centres of supply. (For particulars, see separate estimates.)

Gallons daily.			
For 1st instalment of—	130,000,000	£1,059,810	
2nd „	40,000,000 additional,	557,551	
3rd „	30,000,000 „	117,535	
4th „	30,000,000 „	444,225	
	230,000,000		2,179,121

Total cost of works for obtaining 230,000,000 gallons daily from North Wales, and distributing same to existing centres of supply £10,317,205

THAMES SUPPLY.

No. 2. 1st Instalment.

Estimated outlay for works and annual working expenses, capitalized at 25 years' purchase, for obtaining an additional 35,000,000 gallons daily from the Thames, making a total supply of 130,000,000 gallons daily.

The additional supply will probably be required by the several companies in the proportions given in the following Table:—

Name of Company.	Present Supply, 1866.	Additional Supply.	Total Supply.
	Gallons.	Gallons.	Gallons.
New River	23,000,000	5,600,000	28,600,000
East London	19,300,000	7,300,000	26,600,000
Chelsea	8,000,000	1,150,000	9,150,000
Grand Junction	8,250,000	4,350,000	12,600,000
West Middlesex	8,700,000	4,600,000	13,300,000
Southwark and Vauxhall	12,700,000	6,700,000	19,400,000
Lambeth	9,000,000	2,250,000	11,250,000
Kent	6,050,000	3,050,000	9,100,000
	95,000,000	35,000,000	130,000,000

New River Company. Additional quantity required, 5,600,000 gallons daily.

Outlay in works.

Pumping station.—Steam engines, pumps, buildings, &c., 600 horse power, at 100*l.* per horse power		£60,000
Filters, reservoirs, and land, 6,000,000 gallons, at 4,000*l.* per 1,000,000		24,000
Pipe to Maiden Lane, 36 in. diameter, 19½ miles; average thickness, 1⅛ in.; weight per lineal yard, 12 cwt.		
12 cwt. per lineal yard, at 6*l.*	£3 12 0	
Laying and jointing, per lineal yard	0 15 0	
	£4 7 0	
= 7,656*l.* per mile, say 7,500*l.* × 19½ miles		142,500
Carried forward		£226,500

Thames Supply—1st Instalment—*continued.* No. 2.

New River Company—*continued.*

Brought forward		226,500
Contingencies, 10 per cent. on 84,000*l.*	£8,400	
5 per cent. on 142,500*l.*	7,125	
		15,525
		£242,025

Annual working expenses.

Pumping 5,600,000 gallons, lift equal to 270 ft., at 21*s.* per 1,000,000 gallons raised 100 ft.	£5,794 14 9	
Wear and tear, 2*l.* per horse power for power actually employed, 400 horse power	800 0 0	
Filtering 5,600,000 gallons, at 1/6th*d.* per 1,000 gallons	1,419 8 10	
	8,014 3 7	
Annual payment to Thames Conservancy	1,000 0 0	
	£9,014 3 7	
9,014*l.* × 25 years' purchase		225,350
		£467,375

East London Company. Additional quantity required, 7,300,000 gallons daily.

Outlay for works.

Assume Mr. Greaves' parliamentary estimate is sufficient for this quantity	£247,000

Annual working expenses.

Pumping 7,300,000 gallons 200 feet, at same rate as before	£5,595 9 0	
Wear and tear, 2*l.* per horse power for power actually employed, 310 horse power	620 0 0	
Filtering 7,300,000 gallons, at 1/6th*d.*	1,850 7 0	
Annual payment to Thames Conservancy	1,000 0 0	
	£9,065 16 0	
9,066*l.* × 25 years' purchase		226,650
		£473,650

Chelsea Water Company. Additional quantity required, 1,150,000 gallons daily.

Outlay for works.

Pumping engines, buildings, &c., 100 horse power, at 100*l.*		£10,000
Reservoirs, filters, and land for 1,150,000 gallons, say		5,000
		£15,000
Contingencies, 10 per cent.		1,500
		£16,500

Annual working expenses.

Old supply—for extra friction in pipe.		
Pumping 8,000,000 gallons 8 feet	£183 19 3	
New supply.		
Pumping 1,150,000 gallons 232 feet	1,022 10 3	
Wear and tear, 2*l.* per horse power for power actually employed on 60 horse power	120 0 0	
Filtering 1,150,000 gallons	296 10 0	
	£1,622 19 6	
1,623*l.* × 25 years' purchase		40,575
		£57,075

No. 2. Thames Supply—1st Instalment—*continued.*

Grand Junction Company. Additional quantity required, 4,600,000 gallons daily.

Outlay for works.		
Hampton.		
Pumping engines, buildings, &c., 150 horse power, at 100*l.*		£15,000
Reservoirs, filters, land, &c., 4,600,000*l.*, at 4,000*l.* per million		18,400
Kew.		
Pumping engines, buildings, &c., 600 horse power, at 100*l.*		60,000
New pipe to Campden Hill; 4¾ miles, 30 inches diameter, 1 inch thick; weight 9 cwt. per lineal yard at 6*l.*	£2 14 0	
Laying and jointing	0 13 6	
	£3 7 6	
= 5,940*l.* per mile, say 6,000*l.* × 4¾		28,500
Campden Hill.		
Pumping engines, buildings, &c., 50 horse power, at 100*l.*		5,000
Additional service reservoir to contain 4,000,000 gallons, at 5,000*l.* per million		20,000
Contingencies, 5 per cent. on pipes, = 28,500*l.*	£1,425	
10 per cent. on other works, 118,400*l.*	11,840	
		13,265
		£160,165
Annual working expenses.		
Old supply.		
Pumping 8,700,000 gallons, 30 feet lift	£1,000 5 7	
Pumping 2,000,000 gallons, 20 feet lift	153 6 0	
New supply.		
Pumping 4,600,000 gallons, lift 267 feet	4,707 1 6	
Pumping 3,000,000 gallons, lift 100 feet additional	1,149 15 0	
Wear and tear 2*l.* per horse power for power actually employed, 500 horse power	1,000 0 0	
Filtering 4,600,000 gallons at 1/6th*d.*	1,165 3 0	
	£9,175 11 1	
9,175*l.* × 25 years' purchase		229,375
		£389,540

West Middlesex Company. Additional quantity required, 4,350,000 gallons.

Outlay for works.		
Hampton.		
Pumping engines, buildings, &c., 100 horse power, at 100*l.*		£10,000
Reservoirs, filters, land, &c., 4,350,000 gallons, at 4,000*l.* per million		17,400
Hammersmith.		
Pumping engines, buildings, &c., 500 horse power, at 100*l.*		50,000
30-inch main to Campden Hill, 2½ miles, at 6,000*l.*		15,000
24-inch main thence to Barrow Hill, 3½ miles; weight per lineal yard 7 cwt. at 6*l.*	£2 2 0	
Laying and jointing	0 12 6	
Per lineal yard	£2 14 6	
= 4,796*l.* per mile, say 4,800*l.* × 3½ miles		16,800
		£109,200
Contingencies, 5 per cent. on piping, 31,800*l.*	£1,590	
10 per cent. on other works, 77,400*l.*	7,740	
		9,330
Carried forward		£118,530

Thames Supply—1st Instalment—*continued.* No.

West Middlesex Company—*continued.*

Brought forward		£118,530
Annual working expenses.		
Old supply.		
Pumping 8,250,000 gallons 36 feet	£1,138 5 0	
New supply.		
Pumping 4,350,000 gallons 268 feet	4,467 18 6	
Wear and tear, 2*l.* per horse power for power actually employed, 410 horse power	820 0 0	
Filtering 4,350,000 gallons	1,102 12 1	
	£7,528 15 7	
7,529*l.* × 25 years' purchase		188,225
		£306,755

Southwark and Vauxhall Company. Additional quantity required, 6,700,000 gallons.

Outlay for works.		
Hampton.		
Engines, pumps, buildings, &c., 100 horse power, at 100*l.*		£10,000
Reservoirs, filters, land, &c., 6,700,000 gallons, at 4,000*l.* per million		26,800
36-inch main from Hampton to Battersea, 13¼ miles, at 6,500*l.*		86,125
Battersea.		
Engines, pumps, buildings, &c., 850 horse power, at 100*l.*		£85,000
		£207,925
Contingencies, 5 per cent. on piping, 86,125*l.*	£4,306	
10 per cent. on other works, 121,800*l.*	12,180	
		16,486
		£224,411
Annual working expenses.		
Pumping 6,700,000 gallons daily 240 feet	£6,137 9 0	
Wear and tear, 2*l.* per horse power for power actually employed, 620 horse power	1,240 0 0	
Filtering 6,700,000 gallons	1,691 6 5	
	£9,068 15 5	
9,069*l.* × 25 years' purchase		226,725
		£451,136

Lambeth Company. Additional quantity required, 2,250,000 gallons.

Outlay for works.		
Long Ditton.		
Engines, pumps, buildings, &c., 100 horse power, at 100*l.*		£10,000
Reservoirs, filters, land, &c., 2,250,000 gallons, at 4,000*l.* per million		9,000
New 30-inch main to Streatham, 12 miles, at 6,000*l.* per mile		72,000
Brixton.		
Engines, pumps, buildings, &c., 150 horse power, at 100*l.*		15,000
Additional service reservoir to hold 2,500,000 gallons, at 5,000*l.* per million		12,500
		£118,500
Contingencies, 5 per cent. on piping, 72,000*l.*	£3,600	
10 per cent. on other works, 46,500*l.*	4,650	
		8,250
		£126,750
Annual working expenses.		
Pumping 2,250,000 gallons 225 feet	£1,940 4 0	
Wear and tear, 2*l.* per horse power for power actually employed, 150 horse power	300 0 0	
Filtering 2,250,000 gallons	556 8 0	
	£2,796 12 0	
2,796*l.* × 25 years' purchase		69,000
		£196,650

2. Thames Supply—1st Instalment—*continued.*

Kent Company. Additional quantity required, 3,050,000 gallons.

Outlay for works.

Long Ditton.		
Engines, pumps, buildings, &c., 200 horse power, at 100*l.*		£20,000
Reservoirs, filters, &c., 3,050,000 gallons, at 4,000*l.* per million		12,200
30-inch main to Blackheath, 17 miles, at 6,000*l.*		102,000
Service reservoir to contain 3,000,000 gallons at 5,000*l.* per million		15,000
		£149,200
Contingencies, 5 per cent on piping, 102,000*l.*	£5,100	
10 per cent on other works, 47,200*l.*	4,720	
		9,820
		£159,020

Annual working expenses.

Pumping 3,050,000 gallons 194 feet	£2,267 13 9	
Wear and tear, 2*l.* per horse power for power actually employed, 125 horse power	250 0 0	
Filtering 3,050,000 gallons	773 2 0	
	£3,290 15 9	
Annual payment to Thames Conservancy	500 0 0	
	£3,790 15 9	
3,791*l.* × 25 years' purchase		94,775
		£253,795

Summary of Cost.

Company.	Additional Quantity of Water required.	Estimated Outlay in Works.	Estimated annual working Expenses.	Working Expenses capitalized at 25 years' purchase.	Total Cost including annual working Expenses capitalized.
	Gallons.	£	£ *s.* *d.*	£	£
New River	5,600,000	242,025	9,014 3 7	225,350	467,375
East London	7,300,000	247,000	9,065 16 0	226,650	473,650
Chelsea	1,150,000	16,500	1,622 19 6	40,575	57,075
Grand Junction	4,600,000	160,165	9,175 11 1	229,375	389,540
West Middlesex	4,350,000	118,530	7,528 15 7	188,225	306,755
Southwark and Vauxhall	6,700,000	224,411	9,068 15 5	226,725	451,136
Lambeth	2,250,000	126,750	2,796 12 0	69,900	196,650
Kent	3,050,000	159,020	3,790 15 9	94,775	253,795
Totals	35,000,000	1,294,401	52,063 8 11	1,301,575	2,595,976

Annual working expenses of present (1866) supply of 95,000,000 gallons daily:—

Pumping and filtration		£120,000	
Payments to Thames Conservancy by five companies now drawing from Thames		6,400	
New River Company, Payment to Lea Trustees	£1,500		
Hertford sewage	600		
		2,100	
East London Co., Payment to Lea Trustees		2,000	
Present annual cost		£130,500	Capitalized at 25 years = 3,262,500
Total cost of increasing supply from Thames to 130,000,000 gallons daily			£5,858,476

Thames Supply.—2nd Instalment. No. 2.

Estimated outlay for works and annual working expenses, capitalized at 25 years' purchase, for obtaining a further additional supply of 40,000,000 gallons daily, increasing the supply to 170,000,000 gallons daily.

The additional supply will probably be required by the several companies in the proportions given in the following Table:—

Name of Company.	Present Supply, and first additional Supply as already apportioned.	Additional Supply now estimated for.	Total Supply.
	Gallons.	Gallons.	Gallons.
New River	28,600,000	8,580,000	37,180,000
East London	26,600,000	7,980,000	34,580,000
Chelsea	9,150,000	2,835,000	11,985,000
Grand Junction	13,300,000	3,990,000	17,290,000
West Middlesex	12,600,000	3,780,000	16,380,000
Southwark and Vauxhall	19,400,000	5,820,000	25,220,000
Lambeth	11,250,000	3,375,000	14,625,000
Kent	9,100,000	3,640,000	12,740,000
Totals	130,000,000	40,000,000	170,000,000

New River Company. Additional quantity required, 8,580,000 gallons per day.

Outlay for works.

Pumping engines, buildings, &c., 700 horse power, at 100*l.*		£70,000
Filters, reservoirs, land, &c., 8,000,000, at 4,000*l.* per 1,000,000		32,000
New 36-inch main, 19½ miles, at 7,500*l.* per mile		142,500
		244,500
Contingencies, 5 per cent. on piping, 142,500*l.*	£7,125	
10 per cent. on other works, 102,000*l.*	10,200	
		17,325
		£261,825

Annual working expenses.

Pumping 14,180,000 gallons 290 feet	£15,760 0 0	
Wear and tear, 2*l.* per horse power for power actually employed, 465 horse power	930 0 0	
Filtration, 14,180,000 galls.	3,677 11 1	
Payment to Thames Conservancy	2,000 0 0	
	£22,367 11 1	
Deduct, allowed in estimate for 1st instalment	8,214 0 0	
	£14,153 11 1	
14,153*l.* × 25 years' purchase		353,850
		£615,675

East London Company. Additional quantity required, 7,980,000 gallons.

Outlay for works.

Assume same estimate as for first quantity, *i.e.*, Mr. Greaves' parliamentary estimate		£247,000

Annual working expenses.

Pumping 15,280,000 gallons 200 feet	£11,714 2 6	
Wear and tear, 2*l.* per horse power for power actually employed, 330 horse power	660 0 0	
Filtering 15,280,000 gallons	3,873 1 1	
Payments to Thames Conservancy	2,000 0 0	
	£18,247 3 7	
Deduct, allowed for 1st instalment, in previous estimate	8,446 0 0	
	£9,801 3 7	
9,801*l.* × 25 years		245,025
		£492,025

No. 2. Thames Supply—2nd Instalment—*continued.*

Chelsea Company. Additional quantity required, 2,835,000 gallons daily.

Outlay for works.		
Engines, pumps, buildings, &c., 300 horse power, at 100*l.*		£30,000
Filters, reservoirs, land, &c., 2,835,000 gallons, at 4,000*l.* per 1,000,000		11,340
New 30-inch main to Putney Heath, 6 miles, at 6,000*l.*		36,000
Additional service reservoir, to contain 2,000,000 gallons, at 5,000*l.* per 1,000,000		10,000
		£87,340
Contingencies, 5 per cent. on piping, 36,000*l.*	£1,800	
10 per cent. on other works, 51,340*l.*	5,134	
		6,934
		£94,274
Annual working expenses.		
Pumping 2,835,000 gallons 202 feet	£2,194 15 0	
Wear and tear, 2*l.* per horse power for power actually employed, 200 horse power	400 0 0	
Filtering 2,835,000 gallons	718 12 0	
	£3,313 7 0	
3,314*l.* × 25 years		82,850
		£177,124

Grand Junction Company. Additional quantity required, 3,990,000 gallons daily.

Outlay for works.		
At Hampton.		
Engines, pumps, buildings, &c., 30 horse power, at 100*l.*		£3,000
Reservoirs, filters, land, &c., 4,000,000 gallons, at 4,000*l.*		16,000
New 30-inch main to Kew, 7¼ miles, at 6,000*l.*		43,500
At Kew and Campden Hill.		
Engines, pumps, buildings, &c., 550 horse power, at 100*l.*		55,000
New 36-inch main to Campden Hill, 1¾ miles, at 6,500*l.* per mile		30,875
New 30-inch main into higher parts of Paddington district, say 3 miles, at 6,000*l.*		18,000
		£166,375
Contingencies, 5 per cent. on piping, 92,375*l.*	£4,619	
10 per cent. on other works, 74,000*l.*	7,400	
		12,019
		£178,394
Annual working expenses.		
Pumping 3,990,000 gallons 172 feet	£2,630 3 4	
Pumping 2,500,000 gallons 100 feet additional	958 2 6	
Wear and tear, 2*l.* per horse power for power actually employed, 370 horse power	740 0 0	
Filtering 3,990,000 gallons	1,044 8 4	
	£5,372 14 2	
5,373*l.* × 25 years' purchase		134,325
		£312,719

Thames Supply—2nd Instalment—*continued.* No

West Middlesex Company. Additional quantity required, 3,780,000 gallons daily.

Outlay for works.		
Hampton.		
Engines, pumps, buildings, 30 horse power, at 100*l.*		£3,000
Reservoirs, filters, land, &c., 3,780,000, at 4,000*l.* per 1,000,000		15,120
3-feet main from Hampton to Barnes, 9 miles, at 6,500*l.* per mile		58,500
Extra for crossing the Thames		5,000
Hammersmith.		
Engines, pumps, buildings, &c., 450 horse power, at 100*l.*		45,000
30-inch main to Campden Hill, as before		15,000
24 „ „ to Barrow Hill		16,800
Additional service reservoir, 2,000,000 gallons, at 5,000*l.*		10,000
		£168,420
Contingencies, 5 per cent. on piping, 95,300*l.*	£4,765	
10 per cent. on other works, 73,120*l.*	7,312	
		12,077
		£180,497
Annual working expenses.		
Pumping 3,780,000 gallons 212 feet	£3,071 4 3	
Wear and tear, 2*l.* per horse power for power actually employed, 320 horse power	640 0 0	
Filtering 3,780,000 gallons	958 2 6	
	£4,669 6 9	
4,669*l.* × 25 years		116,725
		£297,222

Southwark and Vauxhall Company. Additional quantity required, 5,820,000 gallons daily.

Outlay for works.		
Hampton.		
Engines, pumps, buildings, &c., 350 horse power, at 100*l.*		£35,000
Filters, reservoirs, land, &c., 6,000,000, at 4,000*l.*		24,000
Battersea.		
Engines, pumps, buildings, &c., 750 horse power, at 100*l.*		75,000
Additional store or service reservoir, to contain 5,000,000 gallons, at 5,000*l.*		25,000
		£159,000
Contingencies, 10 per cent.		15,900
		£174,900
Annual working expenses.		
Pumping 12,520,000 gallons 306 feet	£14,682 15 4	
Deduct, allowed for 1st instalment in previous estimate	6,137 9 0	
	£8,545 6 4	
Wear and tear, 2*l.* per horse power for power actually employed, 700 horse power	1,400 0 0	
Filtering 5,820,000 gallons	1,475 4 2	
Additional payment to Thames Conservancy, for abstraction of water beyond quantity now authorized	1,000 0 0	
	£12,420 10 6	
12,420*l.* × 25 years' purchase		310,500
		£485,400

No. 2. Thames Supply—2nd Instalment—*continued.*

Lambeth Company. Additional quantity required, 3,375,000 gallons daily.

Outlay for works.—Long Ditton.

Engines, pumps, buildings, &c., 200 horse power, at 100*l.*		£20,000
Reservoirs, filters, &c., 3,375,000 gallons, at 4,000*l.*		13,500
Brixton.		
Engines, pumps, buildings, &c., 200 horse power, at 100*l.*		20,000
		£53,500
Contingencies, 10 per cent.		5,350
		£58,850

Annual working expenses

Pumping 5,625,000 gallons 246 feet	£5,303	4	6
Wear and tear, 2*l.* per horse power for power actually employed, 250 horse power	500	0	0
Filtering 5,625,000 gallons	1,425	15	7
	7,229	0	1
Deduct, allowed for first instalment in previous estimate	2,496	0	0
	£4,733	0	1

4,733*l.* × 25 years' purchase	£118,325
	£177,175

Kent Company. Additional quantity required, 3,640,000 gallons daily.

Outlay for works.—Long Ditton.

Engines, pumps, buildings, &c., 400 horse power, at 100*l.*	£40,000
Reservoirs, filters, land, &c., 3,640,000 at 4,000*l.*	14,560
	£54,560
Contingencies, 10 per cent.	5,456
	£60,016

Annual working expenses.

Pumping 6,690,000 gallons 282 feet	£7,230	6	4
Wear and tear, 2*l.* per horse power for power actually employed, 270 horse power	540	0	0
Filtering 6,690,000 gallons	1,695	14	7
Payment to Thames Conservancy	1,000	0	0
	£10,466	0	11
Deduct, allowed for first instalment in previous estimate	3,541	0	0
	£6,925	0	11

6,925*l.* × 25 years' purchase	173,125
	£233,141

SUMMARY OF COST.

Company.	Additional Quantity of Water required.	Estimated Outlay in Works.	Estimated annual working Expenses.	Working Expenses capitalized at 25 years' purchase.	Total Cost, including annual working Expense capitalized.
	Gallons.	£	£ *s.* *d.*	£	£
New River	8,580,000	261,825	14,153 11 1	353,850	615,675
East London	7,980,000	247,000	9,801 3 7	245,025	492,025
Chelsea	2,835,000	94,274	3,313 7 0	82,850	177,124
Grand Junction	3,990,000	178,394	5,372 14 2	134,325	312,719
West Middlesex	3,780,000	180,497	4,669 6 9	116,725	297,222
Southwark and Vauxhall	5,820,000	174,900	12,420 10 6	310,500	485,400
Lambeth	3,375,000	58,850	4,733 0 1	118,325	177,175
Kent	3,640,000	60,016	6,925 0 11	173,125	233,141
Totals	40,000,000	1,255,756	61,388 14 1	1,534,725	2,790,481

Approximate estimate of cost of storage reservoirs on the Thames, to be constructed before more than an average quantity of 154,000,000 gallons per day can be obtained	1,500,000
	£4,290,481
Amount of outlay in works and annual working expenses capitalized of first instalment, and present annual working expenses capitalized.—See summary at end of estimate of first instalment	5,858,476
Total cost of increasing supply from Thames to 170,000,000 gallons daily	£10,148,957

THAMES SUPPLY—3rd Instalment. No. 2.

ESTIMATED OUTLAY for works and annual working expenses, capitalized at 25 years' purchase, for obtaining a further additional supply of 30,000,000 gallons daily, increasing the supply to 200,000,000 gallons daily.

The additional supply will probably be required by the several companies in the proportions given in the following table:—

Name of Company.	Present Supply, and first and second additional Supplies as already apportioned.	Additional Supply now estimated for.	Total Supply.
	Gallons.	Gallons.	Gallons.
New River	37,180,000	6,500,000	43,680,000
East London	34,580,000	6,000,000	40,580,000
Chelsea	11,985,000	1,500,000	13,485,000
Grand Junction	17,290,000	3,000,000	20,290,000
West Middlesex	16,380,000	3,000,000	19,380,000
Southwark and Vauxhall	25,220,000	4,000,000	29,220,000
Lambeth	14,625,000	2,500,000	17,125,000
Kent	12,740,000	3,500,000	16,240,000
Totals	170,000,000	30,000,000	200,000,000

New River Company. Additional quantity required, 6,500,000 gallons daily.

Outlay for works.

Pumping engines, buildings, &c., 850 horse power, at 100*l.*	£85,000
Filters, reservoirs, &c., 6,500,000 gallons, at 4,000*l.*	26,000
Additional service reservoirs, 3,000,000 gallons, at 5,000*l.*	15,000
	£126,000
Contingencies, 10 per cent.	12,600

Annual working expenses.

Pumping 20,680,000 gallons 330 feet	£26,154	10	3
Wear and tear, 2*l.* per horse power for power actually employed, 570 horse power	1,140	0	0
Filtering 20,680,000 gallons	5,246	16	1
Payments to Thames Conservancy	2,000	0	0
	£34,541	6	4
Deduct, allowed in former estimates for first and second instalments	21,437	11	1
	£13,103	15	3

13,104*l.* × 25 years	327,600
	£466,200

No. 2. Thames Supply—3rd Instalment—*continued.*

East London Company. Additional quantity required, 6,000,000 gallons daily.

Outlay for works.

Engines, pumps, buildings, &c., 600 horse power, at 100*l.*		£60,000
Reservoirs, filters, &c., 6,000,000 gallons, at 4,000*l.*		24,000
Service reservoir, 3,000,000 gallons, at 5,000*l.*		15,000
	£99,000	
Contingencies, 10 per cent.		9,900
	£108,900	

Annual working expenses.

Pumping 21,280,000 gallons 240 feet	£19,573 6 0	
Wear and tear, 2*l.* per horse power for power actually employed, 430 horse power	860 0 0	
Filtering 21,280,000 gallons	5,393 17 9	
Payments to Thames Conservancy	2,000 0 0	
	£27,827 3 9	
Deduct, allowed in previous estimates for first and second instalments	17,587 3 7	
	£10,240 0 2	
10,240*l.* × 25 years' purchase		256,000
		£364,900

Chelsea Company. Additional quantity required, 1,500,000 gallons daily.

Outlay for works.

Engines, pumps, buildings, &c., 150 horse power, at 100*l.*		£15,000
Filters, reservoirs, &c., 1,500,000 gallons, at 4,000*l.*		6,000
	£21,000	
Contingencies, 10 per cent.		2,100
	£23,100	

Annual working expenses.

Pumping 1,500,000 gallons 208 feet	£1,195 14 9	
Wear and tear, 2*l.* per horse power for power actually employed, 100 horse power	200 0 0	
Filtration, 1,500,000 gallons	380 4 2	
	£1,775 18 11	
1,776*l.* × 25 years' purchase		44,400
		£67,500

Grand Junction Company. Additional quantity required, 3,000,000 gallons daily.

Outlay for works.

Hampton.

Engines, pumps, buildings, &c., 70 horse power		£7,000
Reservoirs, filters, land, &c., 3,000,000 gallons, at 4,000*l.*		12,000

Kew and Campden Hill.

Engines, pumps, and buildings, 400 horse power		40,000
Additional service reservoir, say 3,000,000 gallons at 5,000*l.*		15,000
	£74,000	
Contingencies, 10 per cent.		7,400
	£81,400	

Annual working expenses.

Pumping 6,990,000 gallons 215 feet	£5,759 13 6	
Deduct, allowed in previous estimate	2,630 3 4	
	£3,129 10 2	
Carried forward		£81,400

Thames Supply—3rd Instalment—*continued.* No.

Grand Junction Company—*continued.*

Amount brought forward		£81,400
Pumping 2,500,000 gallons 100 feet additional	958 2 6	
Wear and tear, 2*l.* per horse power for power actually employed, 340 horse power	680 0 0	
Filtering 3,000,000 gallons	760 8 4	
	£5,528 1 0	
5,528*l.* × 25 years' purchase		138,200
		£219,600

West Middlesex Company. Additional quantity, 3,000,000 gallons daily.

Outlay for works.

Hampton.

Engines, pumps, buildings, &c., 25 horse power, at 100*l.*		£2,500
Reservoirs, filters, land, &c., 3,000,000 gallons, at 4,000*l.*		12,000

Hammersmith.

Engines, pumps, buildings, &c., 550 horse power, at 100*l.*		55,000
Additional service reservoir, 3,000,000 gallons, at 5,000*l.*		15,000
	£84,500	
Contingencies, 10 per cent.		8,450
	£92,950	

Annual working expenses.

Pumping 3,000,000 gallons 25 feet	£287 8 9	
Ditto 11,130,000 gallons 210 feet	8,957 14 0	
	£9,245 2 9	
Deduct amounts allowed in previous estimates	5,976 11 10	
	£3,268 10 11	
Wear and tear, 2*l.* per horse power for power actually employed, 340 horse power	680 0 0	
Filtering 3,000,000 gallons	760 8 4	
	£4,708 19 3	
4,709*l.* × 25 years' purchase		117,725
		£210,675

Southwark and Vauxhall Company. Additional quantity required, 4,000,000 gallons daily.

Outlay for works.

Hampton.

Engines, pumps, buildings, &c., 120 horse power, at 100*l.*		£12,000
Filters, reservoirs, &c., 4,000,000 gallons, at 4,000*l.*		16,000

Battersea.

Engines, pumps, buildings, &c., 500 horse power, at 100*l.*		50,000
	£78,000	
Contingencies, 10 per cent.		7,800
		£85,800

Annual working expenses:

Pumping 4,000,000 gallons 306 feet	£4,690 19 7	
Wear and tear, 2*l.* per horse power for power actually employed, 425 horse power	850 0 0	
Filtering 4,000,000 gallons	1,013 17 9	
	£6,554 17 4	
6,555*l.* × 25 years' purchase		163,875
		£249,675

No. 2.

2. Thames Supply—3rd Instalment—*continued.*

Lambeth Company. Additional quantity required, 2,500,000 gallons daily.

Outlay for works.

Long Ditton.		
Engines, pumps, buildings, &c., 200 horse power, at 100*l.*		£20,000
Reservoirs, filters, land, &c., 2,500,000 gallons, at 4,000*l.*		10,000
Brixton.		
Engines, pumps, buildings, &c., 200 horse power, at 100*l.*		20,000
Additional service reservoir, 2,000,000 gallons, at 5,000*l.*		10,000
		£60,000
Contingencies, 10 per cent.		6,000
		£66,000

Annual working expenses.

Pumping 8,125,000 gallons 293 feet	£9,123 15 0	
Wear and tear, 2*l.* per horse power for power actually employed, 300 horse power	600 0 0	
Filtering 8,125,000 gallons	2,059 9 3	
	£11,783 4 3	
Deduct amounts allowed in previous estimates	6,729 0 1	
	£5,054 4 2	
5,054*l.* × 25 years' purchase		126,350
		£192,350

Kent Company. Additional quantity required, 3,500,000 gallons daily.

Outlay for works.

Long Ditton.		
Engines, pumps, buildings, &c., 150 horse power, at 100*l.*		£15,000
Reservoirs, filters, land, &c., 3,500,000 gallons, at 4,000*l.*		14,000
30-in. pipe to Blackheath, 17 miles, at 6,000*l.* per mile		102,000
Additional service reservoir, 2,000,000 gallons, at 5,000*l.*		10,000
		£141,000
Contingencies—		
5 per cent. on piping	£5,100	
10 per cent. on other works	3,900	
		9,000

Annual working expenses.

Pumping 10,190,000 gallons 228 feet	£8,851 14 8	
Wear and tear, 2*l.* per horse power for power actually employed, 90 horse power	180 0 0	
Filtering 10,190,000 gallons	2,582 3 9	
Payment to Thames Conservancy	1,000 0 0	
	£12,613 18 5	
Deduct, allowed in previous estimates	9,926 0 11	
	£2,687 17 6	
2,688*l.* × 25 years' purchase		67,200
		£217,200

Thames Supply—3rd Instalment—*continued.*

Summary of Cost.

Company.	Additional Quantity of Water required.	Estimated Outlay in Works.	Estimated annual working Expenses.	Working Expenses capitalized at 25 years' purchase.	Total Cost, including annual working Expenses capitalized.
	Gallons.	£	£ *s.* *d.*	£	£
New River	6,500,000	138,600	13,104 0 0	327,600	466,200
East London	6,000,000	108,900	10,240 0 0	256,000	364,900
Chelsea	1,500,000	23,100	1,776 0 0	44,400	67,500
Grand Junction	3,000,000	81,400	5,528 0 0	138,200	219,600
West Middlesex	3,000,000	92,950	4,709 0 0	117,725	210,675
Southwarkand Vauxhall	4,000,000	85,800	6,555 0 0	163,875	249,675
Lambeth	2,500,000	66,000	5,054 0 0	126,350	192,350
Kent	3,500,000	150,000	2,688 0 0	67,200	217,200
Totals	30,000,000	746,750	49,654 0 0	1,241,350	1,988,100

Amount of outlay in works and annual working expenses capitalized of first and second instalments, present annual working expenses capitalized, and cost of storage reservoirs on the Thames.—See summaries at end of estimates of first and second additional instalments	10,148,957
Total cost of increasing the supply from the Thames to 200,000,000 gallons daily	£12,137,057

Thames Supply.—4th Instalment.

Estimated Outlay in works and annual working expenses, capitalized at 25 years' purchase, for obtaining a further additional supply of 30,000,000 gallons daily, increasing the supply to 230,000,000 gallons daily.

The additional supply will probably be required by the several companies in the proportions given in the following table:—

Name of Company.	Present Supply, and first, second, and third additional Supplies, as already apportioned.	Additional Supply now estimated for.	Total Supply.
	Gallons.	Gallons.	Gallons.
New River	43,680,000	6,500,000	50,180,000
East London	40,580,000	6,000,000	46,580,000
Chelsea	13,485,000	1,500,000	14,985,000
Grand Junction	20,290,000	3,000,000	23,290,000
West Middlesex	19,380,000	3,000,000	22,380,000
Southwark and Vauxhall	29,220,000	4,500,000	33,720,000
Lambeth	17,125,000	2,500,000	19,625,000
Kent	16,240,000	3,000,000	19,240,000
Totals	200,000,000	30,000,000	230,000,000

New River Company. Additional quantity required, 6,500,000 gallons daily.

Outlay for works.

Engines, pumps, buildings, &c., 510 horse power, at 100*l.*		£51,000
Reservoirs, filters, land, &c., 6,500,000 gallons, at 4,000*l.*		26,000
New 36-in. main to Maiden Lane, 19½ miles, at 7,500*l.*		142,500
Additional service reservoirs, 3,500,000 gallons, at 5,000*l.*		17,500
		£237,000
Contingencies—		
5 per cent. on piping	£7,125	
10 per cent. on other works	9,450	
		16,575
Amount carried forward		£253,575

No. 2. Thames Supply—4th Instalment—*continued.*

New River Company—*continued.*

Amount brought forward				£253,575
Annual working expenses.				
Pumping 27,180,000 gallons 310 feet	£32,291	17	6	
Deduct, allowed in previous estimate	26,154	10	3	
	6,137	7	3	
Wear and tear, 2*l.* per horse power for power actually employed, 340 horse power	680	0	0	
Filtering 6,500,000 gallons	1,647	11	4	
	£8,464	18	7	
8,465*l.* × 25 years' purchase				211,625
				£465,200

East London Company. Additional quantity required, 6,000,000 gallons daily.

Outlay for works.				
Engines, pumps, buildings, &c., 300 horse power, at 100*l.*				£30,000
Reservoirs, filters, land, &c., 6,000,000 gallons, at 4,000*l.*				24,000
New 36-in. main to Hornsey, 20 miles, at 6,500*l.*				130,000
Service reservoir, 3,000,000 gallons, at 5,000*l.*				15,000
				£199,000
Contingencies—				
5 per cent. on piping	£6,500			
10 per cent. on other works	6,900			
				13,400
Annual working expenses.				
Pumping 27,280,000 gallons 220 feet	£23,001	2	8	
Deduct, allowed in previous estimates	19,573	6	0	
	£3,427	16	8	
Wear and tear, 2*l.* per horse power for power actually employed, 200 horse power	400	0	0	
Filtering 6,000,000 gallons	1,520	16	8	
	£5,348	13	4	
5,349*l.* × 25 years' purchase				133,725
				£346,125

Chelsea Company. Additional quantity required, 1,500,000 gallons daily.

Outlay for works.				
Engines, pumps, buildings, &c., 200 horse power, at 100*l.*				20,000
Reservoirs, filters, land, &c., 1,500,000 gallons, at 4,000*l.*				6,000
Service reservoirs, 1,500,000 gallons, at 5,000*l.*				7,500
				£33,500
Contingencies, 10 per cent.				3,350
				£36,850
Annual working expenses.				
Pumping 1,500,000 gallons 217 feet	£1,250	7	0	
Wear and tear, 2*l.* per horse power for power actually employed, 100 horse power	200	0	0	
Filtering 1,500,000 gallons	380	4	2	
	£1,830	11	2	
1,830*l.* × 25 years' purchase				45,750
				£82,600

Thames Supply—4th Instalment—*continued.*

Grand Junction Company. Additional quantity required, 3,000,000 gallons daily.

Outlay for works.				
Hampton.				
Engines, pumps, buildings, &c., 175 horse power				£17,500
Reservoirs, filters, land, &c., 3,000,000, at 4,000*l.*				12,000
Kew and Campden Hill.				
Engines, pumps, buildings, &c., 450 horse power				45,000
Service reservoir, 1,500,000 gallons, at 5,000*l.*				7,500
				£82,000
Contingencies, 10 per cent.				8,200
				£90,200
Annual working expenses.				
Pumping 9,990,000 gallons 277 feet	£10,605	8	4	
Deduct, allowed in previous estimate	5,759	13	6	
	£4,845	14	10	
Pumping 1,000,000 gallons 100 feet additional	383	5	0	
Wear and tear, 2*l.* per horse power for power actually employed, 400 horse power	800	0	0	
Filtering 3,000,000 gallons	760	8	4	
	£6,789	8	2	
6,789*l.* × 25 years' purchase				£169,725
				£259,925

West Middlesex Company. Additional quantity required, 3,000,000 gallons daily.

Outlay for works.				
Hampton.				
Engines, pumps, buildings, &c., 100 horse power				£10,000
Reservoirs, filters, land, &c., 3,000,000, at 4,000*l.*				12,000
Hammersmith.				
Engines, pumps, buildings, &c., 700 horse power				70,000
				£92,000
Contingencies, 10 per cent.				9,200
				£101,200
Annual working expenses.				
Pumping 9,780,000 gallons 45 feet	£1,683	13	8	
Pumping 14,130,000 gallons 242 feet	13,105	1	6	
	£14,788	15	2	
Deduct, allowed in previous estimates, 649*l.* 12*s.* 2*d.* + 8,957*l.* 14*s.* =	9,607	6	2	
	£5,181	9	0	
Wear and tear, 2*l.* per horse power for power actually employed, 500 horse power	1,000	0	0	
Filtering 3,000,000 gallons	760	8	4	
	£6,941	17	4	
6,942*l.* × 25 years' purchase				173,550
				£274,750

No. 2. Thames Supply—4th Instalment—*continued.*

Southwark and Vauxhall Company. Additional quantity required, 4,500,000 gallons daily.

Outlay in works.		
New 36-in. main to Battersea, 13½ miles, at 6,500*l.*		£86,125
Reservoirs, filters, land, &c., 4,500,000 gallons, at 4,000*l.*		18,000
Battersea.		
Engines, pumps, buildings, &c., 550 horse power, at 100*l.*		55,000
Store or service reservoir, 4,000,000 gallons, at 5,000*l.*		20,000
		£179,125
Contingencies—		
5 per cent. on piping	£4,307	
10 per cent. on other works	9,300	
		13,607
		£192,732
Annual working expenses.		
Pumping 21,020,000 gallons 266 feet	£21,428 15 0	
Deduct, allowed in previous estimates	19,373 14 11	
	£2,055 0 1	
Wear and tear, 2*l.* per horse power for power actually employed, 380 horse power	760 0 0	
Filtering 4,500,000 gallons	1,140 12 6	
	£3,955 12 7	
3,956*l.* × 25 years' purchase		98,900
		£291,632

Lambeth Company. Additional quantity required, 2,500,000 gallons daily.

Outlay for works.		
Long Ditton.		
Engines, pumps, buildings, &c., 60 horse power, at 100*l.*		£6,000
Reservoirs, filters, land, &c., 2,500,000 gallons, at 4,000*l.*		10,000
New 30-inch main to Streatham, 12 miles, at 6,000*l.*		72,000
Brixton.		
Engines, pumps, buildings, &c., 75 horse power, at 100*l.*		7,500
		£95,500
Contingencies, 5 per cent. on piping	£3,600	
10 per cent. on other works	2,350	
		5,950
		£101,450
Annual working expenses.		
Pumping 10,625,000 gallons 260 feet	£10,587 5 6	
Deduct, allowed in previous estimates	9,123 15 0	
	£1,463 10 6	
Wear and tear, 2*l.* per horse power actually employed, 120 horse power	240 0 0	
Filtering 2,500,000 gallons, at ⅛*d.*	633 13 6	
	£2,337 4 0	
2,337*l.* × 25 years' purchase		58,425
		£159,875

No. 2. Thames Supply—4th Instalment—*continued.*

Kent Company. Additional quantity required, 3,000,000 gallons daily.

Outlay for works.		
Engines, pumps, buildings, &c., 270 horse power		£27,000
Reservoirs, filters, land, &c., 3,000,000 gallons, at 4,000*l.*		12,000
Service reservoir, 1,500,000 gallons, at 5,000*l.*		7,500
		£46,500
Contingencies, 10 per cent.		4,650
		£51,150
Annual working expenses.		
Pumping 13,190,000 gallons 245 feet	£12,384 18 4	
Deduct allowed in previous estimates	8,851 14 8	
	£3,533 3 8	
Wear and tear, 2*l.* per horse power for power actually employed, 200 horse power	400 0 0	
Filtering 3,000,000 gallons	760 8 4	
	£4,693 12 0	
4,694*l.* × 25 years' purchase		117,350
		£168,500

Summary of Cost.

Company.	Additional Quantity of Water required.	Estimated Outlay in Works.	Estimated annual working Expenses.	Working Expenses capitalized at 25 Years' purchase.	Total Cost, including annual working Expenses capitalized.
	Gallons.	£	£ s. d.	£	£
New River	6,500,000	253,575	8,465 0 0	211,625	465,200
East London	6,000,000	212,400	5,349 0 0	133,725	346,125
Chelsea	1,500,000	36,850	1,830 0 0	45,750	82,600
Grand Junction	3,000,000	90,200	6,789 0 0	169,725	259,925
West Middlesex	3,000,000	101,200	6,942 0 0	173,550	274,750
Southwark & Vauxhall	4,500,000	192,732	3,956 0 0	98,900	291,632
Lambeth	2,500,000	101,450	2,337 0 0	58,425	159,875
Kent	3,000,000	51,150	4,694 0 0	117,350	168,500
Totals	30,000,000	1,039,557	40,362 0 0	1,009,050	2,048,607

Amount of outlay in works and annual working expenses capitalized of first, second, and third instalments, present annual working expenses capitalized, and cost of storage reservoirs on the Thames, see summaries at end of estimate of first, second, and third instalments	12,137,057
Total cost of increasing the supply from the Thames to 230,000,000 gallons per day	£14,185,664

No. 2. THAMES SUPPLY.—SUMMARY of ESTIMATES for increasing the Supply from the Thames. No.

Quantity of Water. Gallons per Day on Average of Year.	Outlay in Works.	Annual Working Expenses.	Working Expenses capitalized.	Total Cost of additional Supply.	Total Cost of whole Supply.
	£	Estimated at £	£	£	£
Present (1866) supply 95,000,000 gallons	—	130,500	3,262,500	—	3,262,500
130,000,000 gallons, or additional supply of 35,000,000 gallons	1,294,401	52,063	1,301,575	2,595,976	5,858,476
170,000,000 gallons, or further additional supply of 40,000,000 gallons	1,255,756 and 1,500,000 (store reservoirs.)	61,389	1,534,725	4,290,481	10,148,957
200,000,000 gallons, or further additional supply of 30,000,000 gallons	746,750	49,654	1,241,350	1,988,100	12,137,057
230,000,000 gallons, or further additional supply of 30,000,000 gallons	1,039,557	40,362	1,009,050	2,048,607	14,185,664
300,000,000 gallons, or further additional supply of 70,000,000 gallons, at same rate of cost as for preceding instalments, including additional store reservoirs	3,026,314	105,502	2,637,550	5,663,864	19,849,528

APPENDIX N.

METROPOLITAN WATER SUPPLY IN 1866, 1867, AND 1868.

TABLE of the AVERAGE NUMBER of GALLONS of WATER supplied *Daily* by the several METROPOLITAN WATER COMPANIES in the Year 1866.—(Extracted from the Returns of the Registrar General.)

Month.	From the Thames.						From the Lea Valley.			From Chalk Wells in Kent.	TOTAL.
	Chelsea.	West Middlesex.	Southwark and Vauxhall.	Grand Junction.	Lambeth.	TOTAL. Average Daily Quantity.	New River.	East London.	TOTAL. Average Daily Quantity.	Kent.	Average Daily Supply by all the Companies.
January	7,658,800	7,657,423	12,125,000	8,067,112	7,620,200	43,128,535	22,330,000	17,592,000	39,922,000	5,376,676	88,427,211
February	7,207,500	7,503,685	12,165,000	8,029,082	8,248,000	42,154,167	21,442,000	17,566,000	38,788,000	5,118,749	87,061,216
March	7,668,900	7,545,945	12,152,000	8,062,380	7,850,500	43,179,725	21,228,000	17,786,000	39,014,000	5,373,894	87,516,640
April	7,490,300	7,807,567	12,170,000	8,246,186	8,571,300	44,285,353	21,301,000	17,945,000	39,246,000	5,974,100	89,505,453
May	7,385,800	8,397,709	12,175,000	8,853,729	8,904,800	45,719,038	23,092,000	18,357,000	41,449,000	6,025,420	93,193,458
June	8,232,700	8,742,130	12,175,000	9,267,054	9,219,500	47,807,284	23,232,000	19,000,000	42,232,000	6,282,400	96,412,384
July	8,671,600	9,090,414	12,180,000	9,800,484	9,907,400	49,649,898	25,812,000	20,524,885	46,336,885	6,791,427	102,778,210
August	8,284,100	9,000,331	13,653,732	9,439,733	9,884,600	50,262,496	25,579,000	22,558,000	48,137,000	6,835,483	105,234,979
September	8,212,800	8,744,436	13,601,000	8,861,011	9,775,600	49,174,847	23,923,000	20,726,981	44,649,981	6,830,229	100,655,057
October	8,275,300	8,458,552	13,333,740	9,041,221	9,573,100	48,682,376	22,828,000	20,481,000	43,309,000	6,521,529	98,262,905
November	8,060,900	8,052,585	13,255,400	8,384,310	9,085,100	46,838,295	22,815,000	19,685,000	42,500,000	6,503,833	95,842,128
December	7,786,200	7,872,706	13,130,500	8,650,150	8,819,100	46,258,656	21,621,000	19,842,000	41,463,000	6,149,001	93,870,662
Twelve Months	95,020,500	98,842,584	152,151,732	104,509,075	107,406,800	557,930,691	275,183,000	231,863,866	507,046,866	73,782,741	1,138,760,303
Average Daily Supply during the Year	7,918,375	8,236,882	12,679,311	8,709,090	8,950,567	46,494,224	22,931,917	19,321,988	42,253,905	6,148,562	94,646,700

Totals:—
From the Thames - - - - 46,494,224
From the Lea - - - - 42,253,905
From Chalk Wells in Kent - - 6,148,562
Total - - - - 94,646,700

TABLE of the AVERAGE NUMBER of GALLONS of WATER supplied *Daily* by the several METROPOLITAN WATER COMPANIES in the Year 1867.—(Extracted from the Returns of the Registrar General.)

Month.	From the Thames.						From the Lea.			From Chalk Wells in Kent.	TOTAL.
	Chelsea.	West Middlesex.	Southwark and Vauxhall.	Grand Junction.	Lambeth.	TOTAL. Average Daily Quantity.	New River.	East London.	TOTAL. Average Daily Quantity.	Kent.	Average Daily Supply by all the Companies.
January	7,060,300	8,195,541	13,100,000	8,726,626	8,678,000	45,760,467	22,339,000	19,924,000	42,263,000	6,080,750	94,104,217
February	7,912,200	8,666,760	13,100,000	8,845,640	8,090,000	46,614,600	22,296,000	19,975,000	42,271,000	6,250,462	95,136,062
March	7,499,400	8,374,912	13,100,000	8,624,220	8,374,600	45,973,132	21,121,000	18,942,000	40,063,000	6,088,776	92,124,908
April	7,884,900	8,667,501	13,200,000	9,003,981	8,696,000	47,452,382	21,947,000	18,563,000	40,510,000	6,140,625	94,103,007
May	8,360,200	9,228,482	13,225,000	9,920,108	9,250,700	49,984,490	24,772,000	19,207,000	43,979,000	5,901,849	99,865,339
June	8,814,600	9,776,707	13,950,000	10,435,045	9,679,700	52,656,052	26,326,000	20,060,000	46,386,000	7,179,286	106,221,338
July	9,042,800	9,750,965	13,975,000	11,032,742	10,257,800	54,059,307	26,710,000	20,321,152	47,031,152	7,196,708	108,287,167
August	8,875,400	9,326,213	13,978,000	10,409,492	9,592,200	52,181,305	25,617,000	20,192,986	45,809,986	7,039,261	105,030,552
September	8,567,700	8,921,602	13,979,750	10,167,542	9,193,600	50,830,194	25,058,000	19,802,000	44,860,000	6,693,913	102,384,107
October	7,875,200	8,685,121	13,981,340	9,387,510	8,641,500	48,570,671	22,474,000	18,948,657	41,422,657	6,600,000	96,593,328
November	7,560,800	8,230,377	13,983,260	8,953,523	8,937,500	47,665,460	23,532,000	17,983,600	41,415,600	6,112,074	95,293,134
December	7,593,600	7,973,648	13,984,740	8,894,756	8,314,800	46,761,544	23,296,000	17,659,500	40,955,500	6,342,775	94,059,817
Twelve Months	97,047,100	105,797,829	163,557,090	114,401,185	107,706,400	588,509,604	285,488,000	231,578,895	517,066,895	77,626,477	1,183,202,976
Average Daily Supply during the Year	8,087,258	8,816,486	13,629,758	9,533,432	8,975,533	49,042,467	23,790,667	19,298,241	43,088,908	6,468,873	98,600,248

Totals:—
From the Thames - - - - 49,042,467
From the Lea - - - - 43,088,908
From Chalk Wells in Kent - - 6,468,873
Total - - - - 98,600,248

TABLE of the AVERAGE NUMBER of GALLONS of WATER supplied *Daily* by the several METROPOLITAN WATER COMPANIES in the Year 1868.—(Extracted from the Returns of the Registrar General.)

Month.	From the Thames.						From the Lea Valley.			From Chalk Wells in Kent.	TOTAL.
	Chelsea.	West Middlesex.	Southwark and Vauxhall.	Grand Junction.	Lambeth.	TOTAL. Average Daily Quantity.	New River.	East London.	TOTAL. Average Daily Quantity.	Kent.	Average Daily Supply by all the Companies.
January	7,408,000	8,149,316	13,983,245	8,733,763	8,078,600	46,352,929	21,884,000	18,052,900	39,936,900	6,438,116	92,727,945
February	7,378,200	8,068,372	13,984,289	8,816,966	8,401,700	46,649,527	21,647,000	17,834,000	39,481,000	6,630,445	92,760,972
March	7,453,700	8,282,620	13,935,750	9,034,665	8,615,900	47,322,635	21,094,000	17,822,730	38,916,730	6,858,626	93,097,991
April	7,610,400	8,541,342	14,115,536	9,185,067	9,200,300	48,652,645	21,331,000	17,828,500	39,159,500	6,987,871	94,800,016
May	8,661,800	9,517,579	14,158,292	10,328,200	9,736,700	52,402,571	23,037,000	19,120,000	42,057,000	7,779,120	102,238,791
June	9,333,900	9,663,274	14,994,105	10,830,045	10,607,300	55,428,624	25,486,000	19,950,838	45,436,838	8,177,228	109,042,690
July	9,748,100	10,665,049	15,178,697	11,121,734	11,210,400	57,923,980	27,140,000	19,900,000	47,040,000	8,299,857	113,263,837
August	9,317,700	10,014,740	15,410,081	11,417,321	11,046,500	57,206,342	26,869,000	15,848,000	42,717,000	8,065,697	107,989,039
September	9,029,600	9,136,946	15,410,680	10,544,888	10,780,100	54,902,214	24,951,000	18,103,000	43,054,000	7,727,787	105,684,001
October	8,516,700	8,299,676	14,239,719	9,504,187	9,861,900	50,422,182	23,066,000	18,033,800	41,099,800	6,939,135	98,461,117
November	8,252,206	8,041,225	14,177,632	9,217,866	9,566,300	49,255,223	21,812,000	17,612,900	39,424,900	6,820,065	95,500,188
December	7,952,100	7,767,383	13,900,862	9,275,443	9,382,700	48,278,488	19,963,000	17,321,000	37,284,000	6,438,666	92,001,154
Twelve Months	100,632,400	105,977,522	173,798,888	118,010,150	114,188,200	611,937,160	279,180,000	217,127,668	496,607,668	87,162,013	1,195,707,711
Average Daily Supply during the Year	8,388,533	8,831,460	14,483,241	9,834,179	9,707,350	51,244,763	23,265,000	18,118,972	41,383,972	7,263,576	99,892,311

Totals:—

From the Thames	51,244,763
From the Lea	41,383,972
From Chalk Wells in Kent	7,263,576
Total	99,892,311

APPENDIX O.

REPORT on the SELECTION of SAMPLES of WATER in the BASIN of the RIVER THAMES.—By WILLIAM POLE, F.R.S., Member of the Institution of Civil Engineers.

To His Grace the Chairman of the Commission.

MY LORD DUKE, Westminster, May 15, 1868.

1. I HAVE the honour to report that, in obedience to the instructions of the Commission, I have collected various samples of water within the drainage area of the river Thames, and have forwarded them for analysis by Drs. Frankland and Odling.

2. The localities where it was considered desirable that samples should be taken were settled generally by the Commission, and I have carefully carried out the instructions given me, using my own judgment in regard to the exact points of collection. These various points have all been marked on the Ordnance maps for reference.

3. The quantities taken were, as suggested by the chemists, four gallons for the more importtan samples, and two gallons for the rest. The manner of collection was the same as described in my former reports, Appendices A, B, and C.

4. The weather during the collection was generally fine, and, with one or two slight exceptions noticed in their proper places, the main river and the various streams appeared to be in their average condition, neither flooded nor low. It is probable, however, that the condition and quality of the water will vary considerably at different periods of the year, and under different conditions of weather, and will also depend on the quantity of water in the streams.

5. The general hydrography and geology of the basin of the Thames will be seen from the map published in the first Report of the Rivers Pollution Commission, 1866, and a great amount of information respecting it will be found in that publication, as well as in the evidence taken before the Royal Commission on Water Supply.

The portion of the basin above Ditton, the lowest point where water is taken for the supply of the Metropolis, extends over a length and breadth of 80 or 90 miles; its superficial area being given at 3,676 square miles.

The River Thames first assumes importance near the small town of Lechlade, where a number of small streams, forming the head waters of the river, unite. From this point down to Long Ditton, the river follows a tortuous course of about 120 miles in length.

It is joined on the north side by several important tributaries, the principal ones being the Windrush, the Evenlode, the Cherwell, the Thame, and the Colne; while on the south side it receives the waters of the Ock, the Kennet, the Loddon, the Wey, and the Mole.

6. Below Lechlade the Thames is canalized, the water being held up by locks, weirs, and sluices at intervals, forming successive pounds.

There appears to be no traffic worth speaking of in a large portion of this navigation; but the weirs have, I have no doubt, a very beneficial influence on the quality of the water, as its flow over them causes great agitation and aeration, and so must promote considerably the breaking up and oxidation of the organic matter. This fact I think ought to receive more consideration than hitherto in the discussion of the general economy of the river.

7. The samples taken may be divided into four classes, viz.:—

A. The head waters.
B. The main stream of the Thames.
C. The more important tributaries, north and south.
D. Certain outlying waters.

A.—HEAD-WATERS OF THE RIVER.

8. The portion of the Thames basin above Lechlade, containing what I have designated as the head-waters of the river, is above 400 square miles in extent, and is drained by several small streams, the principal of which are the Swillbrook, the Churn (passing through Cirencester), the Colne (Gloucestershire), the Leach, the Ray, and the Cole. Some of these streams were, when I saw them, running above 20 millions of gallons daily.

9. The surface of this large tract of country consists almost entirely of porous rock of the upper and lower oolite formations, interspersed with small areas of impervious fullers earth and lias clay. The oolites are covered generally with only a few inches of soil, and the rain is quickly absorbed. Hence the supply to the streams is principally from springs, the flow off the surface being small and partial except in very heavy rains. I was taken over a portion of the district by Mr. Bravender, of Cirencester, who is well acquainted with the geology and hydrography of the country, and who pointed out to me several of the most important springs.

10. Those in the northern portion of the district come from the lower oolite, being thrown up by the underlying lias clay. Of these I visited the well-known "Seven Springs" at the head of the Churn, which were delivering about 150,000 gallons per day; and a much more important one, the Syreford Spring, at the source of the Colne, furnishing about three or four millions of gallons.

11. The springs from the upper oolite, collected above the impervious bed called "fuller's earth," are more plentiful, and are dispersed over a wider area. They furnish, in fact, the great body of the water flowing down the streams. I saw many of these, and may mention the three following:—

1. The well at Thames Head, from which about 3,000,000 gallons of water are pumped daily, from a depth of about 35 feet below the surface, to supply the upper level of the Thames and Severn Canal.
2. The Boxwell spring, near South Cerney, which when I visited it was delivering about one or two million of gallons per day.
3. The springs in Ampney Park, about two miles east of Cirencester, which are very large, flowing on the 18th March between 5 and 10 millions of gallons.

12. The water from all these oolite springs was very clear and bright, the temperature being about 10° to 11° Cent. Probably the quality may not differ materially in the several places, but I have collected four samples as follows, and they may either be examined separately or mixed together, as the chemists may think best.

Syreford Spring (*Lower Oolite*).

Two gallons, bottle No. 61.

Thames Head Well (*Upper Oolite*).

Two gallons, bottle No. 38.

Ampney Park Springs (*Upper Oolite*).

Two gallons, bottle No. 28.

Boxwell Spring (*Upper Oolite*).

Two gallons, bottle No. 15.

B.—Main Stream of the Thames.

13. The various streams mentioned under the last head unite a little below Lechlade, forming a good wide river, which here becomes navigable, communicating with the south end of the Thames and Severn Canal.

14. The quantity of water passing down the river at this place I estimated roughly on the 18th April at something over 100 millions of gallons per day. In dry seasons it is no doubt much less, and in rains very much more. The water was slightly turbid, the bottom being visible, however, at two or three feet depth; and it had a temperature of 10½° Centigrade.

It is principally furnished by the oolite springs mentioned in the last head, with a little contribution from the chalk hills to the south, and probably some small proportion of surface drainage.

15. The towns of Cirencester, Cricklade, Lechlade, Fairford, Northleach, Swindon, Highworth, and some other small places, lie in the basin above this point, but as no systematic drainage by sewers (except to a small extent at Cirencester) is carried out in any of them, I think it may be said that the only contamination of importance received by the water is from the tilled land. And from the absorbent nature of the ground over nearly the whole of the district, this will naturally be much less than in places where the waters flow over retentive soils.

16. I have taken a sample from the river as it flowed through St. John's Bridge, about half a mile below Lechlade.

Thames at Lechlade.—Four gallons. bottles Nos. 2 and 14.

17. Descending the river from Lechlade, it receives on the north the water of the Windrush, Evenlode, and other small streams, and after a flow of about 27 miles it arrives at

Oxford,

which is the first large town on its banks, and where it receives a large tributary, the Cherwell.

18. With regard to this and the other large towns on the river, my instructions were to take three samples in each case, namely:

1. Immediately above the town, to show the natural quality of the water of the river uninfluenced by the population.
2. At a point below the town, where its drainage becomes mixed with the water.
3. At another point some miles below, but before the river receives any further affluent, or other important source of alteration, the object of this latter sample being to ascertain what change was produced on the quality by the flow.

In cases where, as at Oxford and Reading, a tributary entered at a town, it was necessary to take a sample of that tributary also.

19. Oxford, as I learnt from the borough surveyor, Mr. Field, and from Dr. Adams, of St. John's College (who has paid much attention to these questions), is drained to a considerable extent, though not so thoroughly as the modern system generally requires. There are two principal sewer outfalls, one emptying into the main stream just below Folly Bridge, the other into the Cherwell near the Botanic Gardens; and there are other smaller drains into both rivers.

20. The samples of the main river in the neighbourhood of Oxford were:—

At Midley Lock, about a mile above the town; taken on the 29th April, two gallons, bottle No. 25.

At "the Gut," about three-quarters of a mile below the junction of the Cherwell, same day, two gallons, bottle No. 95.

At the Lock above Abingdon, about seven miles below the place last mentioned; taken 30th April, two gallons, bottle No. 68.

The water at each of these places was tolerably clear, bottom visible at two or three feet deep; the samples near the town were the least so, probably owing to agitation by boating. Temperature about 13° or 14° Cent.

Reading.

21. The next part of the river at which samples were taken was in the neighbourhood of Reading, the object being, as in the case of Oxford, to ascertain the effect of the drainage of the town.

22. Reading, I am informed, has no systematic sewerage; there are some drains which open into the river Kennet as it passes through the town, and which carry off the surface water, but, as far as I can learn, they do not convey much house drainage, although, no doubt, a considerable amount of sewage somehow or other finds its way into the river. There is no drainage directly into the Thames, which is at some distance from the town.

23. Three samples were taken from the Thames in this neighbourhood, namely,

At Caversham Bridge, a little above the town; sample taken 24th April, two gallons, bottle No. 70.

Below the Town, about a quarter of a mile below the junction of the Kennet, and where consequently the river may be supposed to have received the drainage of the town; taken 24th April, two gallons, bottle No. 34.

At Shiplake Mill.—About four or five miles below point No. 2, and just above the entrance of the Loddon. Sample taken 25th April, two gallons, bottle No. 36.

In each of these places the river was tolerably clear, the bottom being visible at two or three feet deep. Temperature about 11° to 12° Cent.

24. Below this the river receives the Loddon, and after passing the town of Henley arrives at

Medmenham,

A point about four or five miles below Henley, where Messrs. McClean and Blackwell, in their plan of 1849, proposed to tap the river, and convey water by an aqueduct to London.

A sample, two gallons, bottle No. 35, was taken on the 25th April, close to Medmenham Abbey; water clear, bottom visible at about three feet depth.

Windsor.

25. The town of Windsor, and the Crown properties in the neighbourhood, are said to be efficiently sewered. The northern slope, drains by a small sewer into the south side of the river, a little west of the bridge leading to Eton, but the chief part of the sewage is conveyed into a sewer built by Government for the drainage of the royal properties, and which empties into the Thames about a mile below Datchett. The suburb of Eton drains, I believe, directly into the river.

26. I was told by a resident near the mouth of the main sewer, that the sewage does not flow regularly into the river, but is admitted by flashes, at intervals. This is not a good plan for the water in the river, as it is unfavourable to the gradual oxidation of the organic matter.

27. I took on 2nd May three samples from the river near this place.

Above Windsor.—About half a mile above the bridge, clear of the town and the sewage; sample two gallons, No. 43; water very clear and clean; bottom visible many feet deep.

Below sewer outlet.—I could not find a convenient place to take this till I came to the ferry at Old Windsor. This is nearly two miles below the mouth of the sewer, and the water, though it continued clear, presented traces of dirt, straw, &c. floating on and in it. Sample two gallons, bottle No. 51.

At Weir above Staines.—The third sample was taken under the Weir above Staines, and just above the entrance of the Hertfordshire Colne. This point is nearly three miles below the last-named one, and five miles below the outlet of the Windsor sewage. Sample two gallons, bottle No. 96; water clear and cleaner looking than at the place of the second sample.

Hampton.

28. The lowest sample of the river was taken on the 4th May, just above the place where the Southwark and Vauxhall, Grand Junction, and West Middlesex Companies take their water; that is, about a mile above the village of Hampton. Sample four gallons, bottles Nos. 67 and 92; water clear, bottom visible 4 or 5 feet deep. Temperature 17° Cent.

C.—Tributaries.

29. It was not considered necessary to take samples of all the tributaries to the Thames. Those selected were the principal ones, namely, the Cherwell, the Thame, and the Colne on the north, and the Kennet, the Loddon, the Wey, and the Mole on the south of the main stream.

The Cherwell.

30. The Cherwell is a large stream, which enters the Thames at Oxford, and drains about 400 square miles of country, consisting chiefly of oolite, Oxford clay, and lias. The quantity of water brought down was large, but I had no means of estimating its amount.

I took on the 29th April a sample at Cox's ferry, a mile or two above Oxford, four gallons, bottles Nos. 60 and 80. Water tolerably clear, like the Thames; temperature 12½° Cent.

The Thame.

31. This is a stream flowing in at Dorchester; it drains between 300 and 400 square miles, to some extent chalk, but principally Kimmeridge clay.

The sample was taken 30th April, at Queenford mill, just above Dorchester; four gallons, bottles Nos. 17 and 29. Water rather turbid, bottom visible at 12 to 18 inches deep; temperature 14° Cent.

The Colne (Hertfordshire).

32. The river Colne forms the outlet for a great body of water issuing by springs from the large area of chalk lying to the north-west of London. Its drainage ground appears by the map to be upwards of 400 square miles in extent, and from its proximity to London, and from the natural purity of its water, it has often been proposed as a source of supply.

The river itself having many mills upon it, it was thought preferable that I should take the sample direct from one of the chalk springs forming its principal feeders, and I chose for the purpose one well known, lying two or three miles above Watford, called the Otter's Pool.

The sample was taken on the 8th April, four gallons, bottles Nos. 56 and 89. The spring was delivering about two and a half millions of gallons per day, and the water was perfectly clear; temperature about 11° Cent.

The Kennet.

33. This river, which is one of the chief feeders of the Thames, drains between 400 and 500 square miles of country, and falls into the main stream a little below Reading.

It comes chiefly from the chalk downs north of Hungerford and Marlborough, and in the lower part of its course flows over clay beds in the valley.

On the 24th April after a few days of showery weather I found it near its junction with the Thames running at a rough estimate about 200 millions of gallons per day.

I took two samples of this river as follows:—

Above Hungerford.—This was taken on the 20th April, about a mile above Hungerford; quantity, 4 gallons; bottles Nos. 24 and 74. Water clear; temperature about 11° Cent.

Above Reading.—This was taken on the 24th April, rear the site of the waterworks pumping station, about two miles above Reading. Quantity 2 gallons; bottle No. 65. The water here was rather turbid, the bottom being, however, visible about 18 inches deep.

The Loddon (Bagshot Sands).

34. The tributary stream called the Loddon, which falls into the south side of the Thames about 5 miles below Reading, drains partly a tract of London clay, and partly, by means of the Blackwater, a district of porous strata known as the "Bagshot Sands," about 200 square miles in extent, and which was some years ago proposed as a source of supply for the metropolis on account of the supposed superiority of its waters.

Instead of taking samples from the Loddon, it was deemed more useful to get them direct from the Bagshot Sand district, and for this purpose I was kindly directed by Professor Rupert Jones, of Sandhurst College, to a small stream which is used for the supply of that establishment and which was stated by him to present a fair sample of the water as naturally flowing from the formation in question. It rises at Wishmoor and runs into the Blackwater near Blackwater station on the Reading and Guildford railway.

The sample, 4 gallons, bottles Nos. 23 and 53, was taken on the 21st April, about a mile above the college; temperature about 11° Cent. The water was clear, but a little coloured by peat, and the channel presented appearances probably due to iron.

The Wey.

35. The Wey drains between 400 and 500 square miles of country, passing through Guildford, and joining the Thames near Weybridge.

Above Guildford it comes principally from the Lower Green-sand formation, with, however, a mixture of chalk water from the neighbourhood of Farnham and Alton. Below Guildford it collects the eastern drainage of the Bagshot Sands.

A sample of the water, 4 gallons, bottles Nos. 37 and 49, was taken on the 21st April about three-quarters of a mile above Godalming; river somewhat in flood and rather turbid; temperature about 13° Cent.

Mole.

36. The River Mole drains about 200 square miles of country; running by Dorking, Leatherhead, and Cobham, and joining the Thames opposite Hampton Court. The upper part of the district above Dorking is chiefly Weald clay, the lower part below Leatherhead, chiefly London clay.

The sample, 4 gallons, bottles Nos. 59 and 84, was taken on the 4th May, about one mile above the junction and above the village of Moulsey. Water dirty and turbid, bottom hardly visible 1 ft. deep.

D.—Outlying Waters.

37. In addition to the waters properly belonging to the drainage area above Ditton, I was instructed to take samples from other parts of the basin which would afford useful information on the subject of the supply of the metropolis. These are as follow:—

River Lea district.

38. The upper waters of the Lea being used for the supply of London by the New River and East London companies, it was considered desirable to have samples, and I accordingly took them, on the 5th May, from three places, as follows:—

Lea proper.—Taken from a point just above Woolmers Park, about three or four miles above Hertford; two gallons, bottle No. 86. Water clear, but with particles of dirt, straw, &c. floating in it. Temperature, about 16° Cent. Quantity, about ten millions of gallons per day.

Mimram.—Taken from the bridge in Panshanger Park, about two or three miles above Hertford; two gallons, bottle No. 3. Water like the last. Temperature, about 14½° Cent. Quantity about the same as the Lea.

Amwell Spring.—This sample, four gallons, bottles Nos. 22 and 76, was taken as pumped from the New River Company's well at Amwell Hill, about a mile below Ware. Water beautifully clear. Temperature, 11° Cent.

Chalk district, south of London.

39. This is a district which it is believed collects a large quantity of water, that at present finds its way into the Thames by the Wandle, the Ravensbourne, and the Darenth, and is to a small extent used by the Kent Water Company for the supply of the south-eastern districts of London.

To obtain a specimen of this water I visited on the 12th of May the waterworks established by Mr. Homersham on the high ground south of Caterham, for the purpose of supplying that place, as well as the neighbouring districts of Godstone, Bletchingly, Nutfield, and Red Hill. The water is pumped from a very deep well, the water standing about 300 or 400 feet below the level of the ground at the pumping station, which is 700 feet above the sea. The water is softened by Dr. Clark's process (as described in Mr. Homersham's evidence), and stored in an underground reservoir for distribution.

The sample, four gallons, bottles Nos. 97 and 100, was taken from the pumping main, as it came directly from the well, and probably represents fairly the chalk water of the North Downs. The temperature was 11° Cent.

Croydon and the Wandle.

40. The object of these samples was to obtain some knowledge as to the operation of the plan now adopted for applying the sewage of Croydon to irrigate land, before it is turned into the River Wandle.

41. The works have been designed and laid out by Mr. Baldwin Latham, the borough engineer, who gave me every assistance in my examination. The town,

containing between 30,000 and 40,000 inhabitants, is amply supplied with water from a well in the chalk, near the centre of the town. The sewerage is systematically laid out, and the sewers draining the greater portion of the area open at the western outskirts of the town, towards the River Wandle. The sewage running from them, which I am told averages about 3,000,000 gallons per day, is first roughly strained, to arrest the larger solid matters, and then is conducted to the irrigation land at Beddington, which has been acquired for the purpose by the town. The whole area of this land is, I am told, about 300 acres, and the drains are so laid out as to carry the sewage to all parts; but only about 20 or 30 acres are under irrigation at one time. The land is on a gentle slope, and the liquid, being turned upon it at the upper end flows over the whole surface, and passes off into drains at the bottom, from which it is conveyed away into the River Wandle, about half way between Carshalton and Mitcham.

42. When I saw the system at work on the 11th May, although the sewage was foul and dirty when it went on to the land, the water running off was quite bright and clear, without any appearance of foul deposit in the channel. I noticed several fine trout in the river, near the point of discharge, as well as in other places farther down.

It is worthy of remark that the plan here adopted, of allowing the sewage to travel slowly over the land, in constant agitation among the blades and stalks of the vegetation, appears to me peculiarly favourable for the oxidation of the impurities by the action of the atmosphere, which I have no doubt powerfully aids the purifying action by vegetable absorption. I noticed, however, that the person working the plan had the power of allowing the sewage, or any portion of it, to run by bye passes directly into the effluent channel, and so into the river, without passing over the fields; a dangerous power, as either through carelessness or design the whole efficacy of the system might thereby be destroyed.

43. I took in this neighbourhood five samples of two gallons each, viz.:—

(1.) *From the well supplying Croydon with water.*
Bottle No. 83, temperature 13½° Cent.

(2.) *Sample of the sewage as it passes on to the land,* after simple straining.
Bottle No. 21, temperature 12° Cent.

(3.) *Sample of the purified sewage water* as it passes into the Wandle after running off the land.
Bottle No. 8, temperature 16° Cent.

(4.) *Sample from the Wandle,* about half a mile below the place where it receives the sewage water.
Bottle No. 90, temperature 14° Cent.

(5.) *Sample from the Wandle,* on Mr. Bidder's property at Mitcham, about a mile below the last-named point.
Bottle No. 94.

44. With regard to the quality of the water in the Wandle, it must be remarked that there are many mills on the stream, above the two points where my samples were taken, and several of these, I am given to understand, turn noxious matters into the river.

List of the Samples.

45. The following is a list of the samples, arranged in order.

Head Waters.

Gallons.
2. Syreford spring.
2. Thames head well.
2. Ampney Park springs.
2. Boxwell spring.

Main Stream.

Miles from Lechlade.	Gallons.	
½	4	At St. John's Bridge.
25½	2	At Midley Lock, above Oxford.
28½	2	At the Gut, below Oxford.
35	2	At the Weir, above Abingdon.
65	2	At Caversham Bridge, above Reading.
66½	2	A little below Reading.
70½	2	At Shiplake.
79	2	At Medmenham.
96½	2	Above Windsor.
104	2	At weir above Staines.
101	2	Below Windsor sewers outfall.
116½	4	At Water Companies' intake at Hampton.

Tributaries.

Gallons.
4 Cherwell.
4 Thame.
4 Chalk spring (Colne).
4 Kennet, above Hungerford.
2 Do., above Reading.
4 Bagshot Sands (Loddon).
4 Wey.
4 Mole.

Outlying Waters.

Gallons.
2 Lea proper } Above Hertford.
2 Mimram }
4 Amwell well.
4 Caterham well.
2 Croydon well.
2 Do. sewage.
2 Do. do. purified.
2 Wandle, after mixture.
2 Do. at Mitcham.

I have, &c.
William Pole.

APPENDIX P.

Returns of the Quantities of Water supplied by the Metropolitan Water Companies in former Years.

CHELSEA WATERWORKS COMPANY.

Return of Average Daily Quantity of Water, and Number of Houses supplied from 1857 to 1867, both inclusive.

Date.	Average daily quantity, gallons.	Number of houses supplied.
1857	5,503,700	25,271
1858	5,780,000	25,584
1859	5,788,700	25,711
1860	5,909,600	25,850
1861	6,233,500	25,936
1862	6,811,600	26,049
1863	7,187,900	26,234
1864	7,977,800	26,362
1865	8,394,700	26,436
1866	7,918,400	26,783
1867	8,087,300	27,077

15th May 1868.

WEST MIDDLESEX WATERWORKS COMPANY.

19, Marylebone Road, W.
16th May 1868.

Sir,

Your letter of the 27th ult. having been referred by the Board of Directors to the Company's Engineer for his report, I am desired to forward you the following statement of the average daily quantity of Water, and of the number of Houses supplied by this Company for the years from 1856 to 1867, both inclusive, viz.:—

Date.	Average Daily Supply in Galls.	Number of Houses.
1856	6,005,293	28,198
1857	6,007,608	28,773
1858	6,191,424	29,300
1859	6,313,248	30,101
1860	6,288,408	30,793
1861	6,716,302	31,441
1862	6,924,744	32,217
1863	7,090,848	33,137
1864	7,499,088	34,198
1865	8,046,000	35,303
1866	8,208,168	36,331
1867	8,790,336	37,570

The Directors have no reliable data upon which they can depend to enable them to furnish you with a return of the number of persons resident in the houses supplied by the Company.

I am, &c.,
W. H. Whiffin, Secretary.

To Dr. Wm. Pole, F.R.S., Secretary, &c.
Royal Commission of Water Supply.

SOUTHWARK AND VAUXHALL WATER-WORKS COMPANY.

RETURN of the AVERAGE DAILY QUANTITY of WATER supplied by the above COMPANY for 12 years, commencing Christmas 1856 and ending Christmas 1867.

Date.	Average Daily Supply in Imperial Gallons.	No. of Houses supplied.
For the year ending—		
Christmas 1856 -	Supplied for 6 days in the week, and a small portion on Sundays. 10,331,122	41,432
,, 1857 -	10,604,537	43,721
,, 1858 -	10,621,349	45,909
,, 1859 -	10,873,415	46,737
,, 1860 -	10,732,458	48,911
,, 1861 -	11,155,000	52,220
,, 1862 -	11,244,177	56,444
,, 1863 -	11,322,431	60,413
,, 1864 -	11,500,231	64,725
,, 1865 -	Supply given 7 days per week. 12,120,778	69,111
,, 1866 -	12,502,000	73,940
,, 1867 -	13,050,563	71,229*

The number of inhabitants in this company's district is roughly estimated at 6½ persons per house.

GRAND JUNCTION WATERWORKS COMPANY.

RETURN of the AVERAGE DAILY QUANTITY of WATER supplied by the above Company for 12 years, commencing Michaelmas 1855, and ending Michaelmas 1867.

Date.	Average Daily Supply in Imperial Gallons.	No. of Houses supplied.
For the year ending—		
Michaelmas 1856 -	5,478,361	17,080
,, 1857 -	6,022,651	17,722
,, 1858 -	6,858,465	18,357
,, 1859 -	8,416,596	18,996
,, 1860 -	7,118,486	19,663
,, 1861 -	7,733,250	20,336
,, 1862 -	8,455,179	21,184
,, 1863 -	8,330,293	22,769
,, 1864 -	8,701,275	23,036
,, 1865 -	9,780,057	24,333
,, 1866 -	9,317,055	26,450
,, 1867 -	9,392,768	27,032

N.B.—The number of inhabitants is roughly estimated in this company's district at nine persons per house.

ERNEST O. LEE,
9th May 1868. Secretary.

LAMBETH WATERWORKS COMPANY.

RETURN of AVERAGE DAILY QUANTITY of WATER and NUMBER of HOUSES supplied from 1857 to 1867, both inclusive.

Date.	Average Daily Quantity. Gallons.	No. of Houses supplied.
1857 - - -	6,052,300	29,295
1858 - - -	5,935,900	30,143
1859 - - -	5,708,200	30,745
1860 - - -	6,026,700	31,571
1861 - - -	6,557,600	32,271
1862 - - -	6,962,700	33,340
1863 - - -	7,765,600	34,353
1864 - - -	8,650,200	35,005
1865 - - -	9,030,400	35,420
1866 - - -	8,950,600	37,165
1867 - - -	8,975,500	39,460

W. S. PHIPPS,
Office of Lambeth Waterworks, Secretary.
175, Kennington Park Road,
14th May 1868.

* The smaller number is in consequence of the number of houses pulled down for railways and improvements.

NEW RIVER COMPANY.

Date.	Average Daily Supply in Gallons.	Average Number of Houses served.
1858 - - -	24,992,334	101,534
1859 - - -	24,988,151	103,514
1860 - - -	20,801,277	105,007
1861 - - -	22,837,000	106,303
1862 - - -	23,260,341	107,977
1863 - - -	23,834,673	109,482
1864 - - -	24,718,452	110,511
1865 - - -	23,496,866	111,447
1866 - - -	22,898,769	112,252
1867 - - -	23,818,231	113,464

12th May 1868. ALEX. INGLIS, Secretary.

EAST LONDON WATERWORKS COMPANY.

Office 16, St. Helen's Place, E.C.,
20th May 1868.

Date.	Gallons pumped daily.	Number of Houses supplied.
	365 days all.	
1830 - - -	4,987,272	43,894
1840 - - -	6,695,624	48,991
1850 - - -	9,908,355	58,129
1851 - - -	10,629,176	59,550
1852 - - -	11,543,521	61,451
1853 - - -	11,981,432	63,605
1854 - - -	13,315,627	66,191
1855 - - -	14,761,954	68,076
1856 - - -	14,562,684	71,059
1857 - - -	14,746,953	71,173
1858 - - -	15,355,447	72,709
1859 - - -	15,754,652	74,601
1860 - - -	15,897,799	76,771
1861 - - -	16,837,278	78,494
1862 - - -	16,941,315	80,387
1863 - - -	17,571,937	83,296
1864 - - -	17,381,104	85,557
1865 - - -	18,333,067	88,340
1866 - - -	19,380,740	91,975
1867 - - -	19,320,576	95,098

E. BATES, Secretary.

KENT WATERWORKS COMPANY.

RETURN of the NUMBER of HOUSES supplied, and the AVERAGE DAILY CONSUMPTION of WATER, from 1839 to 1867.

Date.	Average Daily Supply in Gallons.	Houses supplied.
1839 - - -	360,000	5,600
1840 - - -	380,000	5,832
1841 - - -	399,000	5,985
1842 - - -	409,000	6,308
1843 - - -	437,000	6,547
1844 - - -	470,000	6,939
1845 - - -	600,000	7,681
1846 - - -	923,000	8,381
1847 - - -	1,010,000	9,223
1848 - - -	1,070,000	9,662
1849 - - -	1,258,000	10,456
1850 - - -	1,575,000	11,486
1851 - - -	1,769,000	12,536
1852 - - -	2,000,000	13,588
1853 - - -	2,146,000	14,573
1854 - - -	2,686,000	15,650
1855 - - -	2,757,000	15,716
1856 - - -	2,722,000	16,662
1857 - - -	2,936,000	17,774
1858 - - -	3,415,000	18,875
1859 - - -	3,594,000	20,125
1860 - - -	3,987,000	21,533
1861 - - -	4,546,000	26,362
1862 - - -	4,869,000	28,125
1863 - - -	4,894,000	29,560
1864 - - -	5,284,000	30,802
1865 - - -	5,463,000	32,451
1866 - - -	6,038,000	33,864
1867 - - -	6,520,000	35,607

W. R. MORRIS, Engineer.

PROPOSED

SCHEME FOR THE

SUPPLY OF WATER

TO VARIOUS TOWNS FROM THE LAKE DISTRICTS OF

CUMBERLAND & WESTMORELAND,

By

THOS DALE C.E.

CORPORATION WATERWORKS, HULL.

1865.

Lambley Sta. · Whitfield · Whitley Chap · Slaley · Allendale · Slaggyford Sta. · Kirkhaugh · ALSTON · Dirt Pot · EAST ALLEN WATER

St Johns · Westgate · Weardale · Swinhope · Gamblesby · Melmerby · Covertfold · Ousby · Skirwith · Kirkland · Staingills · Blencarn · Gulgaith · Milburn · Newbiggin · Milburn Grange · Temple Sowerby · Sta. · Kirkby Thore Sta. · Dufton · Long Marton · Cliburn · Morland · Kings Meaburn · Crackenthorpe · APPLEBY · Bongate · Sleagill · Reagill · Great Ormside · Lit. Ormside · Hilton Field · Sandford · Warcop Sta. · Warcop · BROUGH · Plover Riggs · Grosby · Ravensworth · Oddendale · Asby · Coatsforth · Griseburn · Lit. Musgrave · Great Musgrave · Whitewall · Soulby · Kaber · Barras Sta. · Lit. Asby · Grosby · Garret · KIRKBY STEPHEN · Hartley · Waitby Sta. · Smardale · Nateby · ORTON · Wharton · Tebay · Junc. · Tebay · Langdale · Caisgill std. · Rowlane Sta. · Ravenstone Dale · Redding Ho. · Pendragon Castle · Lit. Ings · Haysgill · Beckside · LOWGILL ST. · Firbank · SEDBERGH · Sta. · Millthorpe · Rash · Helmside · St Johns · Middleton · Sta. · Dent · Fold Hos · Stonehouse · Whinshaw · Intack · Highgate · Casterton · Barron · KIRKBY LONSDALE · Sta. · Brunscarr · Chapel le dale · Masongill · Selside · Tunstall · Ingleton · Grassington · Newby · Clapham · Sta. · Austwick · Feizer · Wray · Gt Stainforth · Langcliffe · Giggleswick · SETTLE · Long Preston · Hellifield · Sta. · Bellbusk · Cold Coniston · Cargrave Sta. · Kirkby Malham · Hetton · Rilston · Cracoe · Linton · Grassington · Burnsall · Kilnsey · Coniston · Horton in Ribblesdale · Higher Stufold · Arncliffe · Litton · Kettlewell · Buckden · Starbotton · SKIPTON · Sta. · Broughton · Carlton · Thornton · Cononley Sta. · Addingham · Bolton by Rowland · Gisburn · Bracewell · Barnoldswick · Easburn · Kildwick · Steeton Sta. · CLITHEROE · Longridge · Whalley · Balderstone · Mellor · BLACKBURN · Accrington · Goulds haw · Brindle · BURNLEY · Worsthorn · KEIGHLEY · Sta. · Bingley · Shipley · BRADFORD · ILKLEY · Weston · Leathley · OTLEY · Guisley · Addle · Calverley · Yeadon Sta. · Kirkstall Sta. · Armley Sta. · LEEDS · Whitkirk · Church Gartside · Kippax · Leadsham · Wetherby · Collingham · Harewood · Bardsey · Thorner · Barwick in Elmet · Aberford · Pannal · Spofforth · Kirkby Overblow · Hustwayte · Cowthorpe · Burton Leonard · South Stainley · Copgrove · Staveley · Marton · Farnham · Allerton Mauleverer · KNARESBORO · Hampsthwaite · RIPLEY · Birstal · Rothwell · Mirfield · East Ardsley · CASTLEFORD · HALIFAX · RIVER CALDER · RIVER HODDER · RIVER RIBBLE · RIVER AIRE · RIVER WHARFE · RIVER NIDD · RIVER SWALE · RIVER URE · RIVER TEES · ULLESWATER & HAWESWATER TUNNEL · WESWATER TUNNEL · MAIN PIPE FROM HAWESWATER TO RIVINGTON PIKE

Ramaldkirk · Marwood · Cockfield · Staindrop · Hilton · Ingleton · BARNARD CASTLE · Winston · Whorlton · High Starforth · Bowes · Brignall · Barningham · Wycliffe · Manfield · Cleasby · DARLINGTON · Elstob · Great Stainton · Little Stainton · Brampton · Bardon · Sadberge · Elton · Long Newton · Melsonby · Groft · Kirkby Ravensworth · Gilling · Middleton Tyas · Ct Cawton · Great Smeaton · Welbury · RICHMOND · Muker · Murrick · Downholme · Catterick · Danby Wiske · Langton · East Harlsey · Hawxwell · NORTHALLERTON · Preston · LEYBURN · Patrick Brampton · Wensley · Spennithorne · West Witton · MIDDLEHAM · Thornton Steward · East Witton · BEDALE · Thornton Watlass · Burneston · South Otterington · Ellingstring · High Ellington · MASHAM · Kirklington · THIRSK · West Tanfield · Wath · MELMERBY · Topcliffe · Nunwick · Kirkby Malzeard · Gundall · RIPON · Kirkby Hill · BOROUGHBRIDGE · Aldborough · PATELEY BRIDGE

Mr. Dale's Plan for the Supply of Water from the Lake District

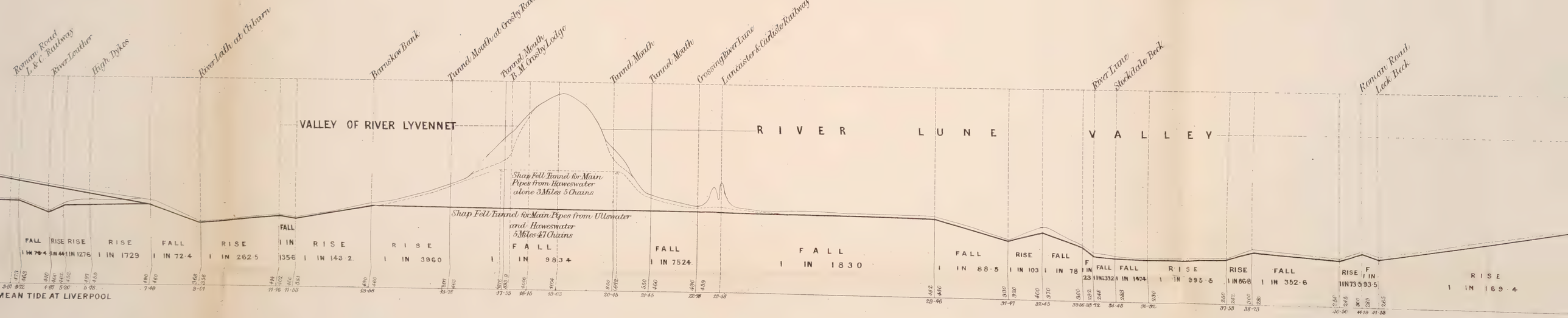
Longitudinal Section

Shewing the

Surface Levels of Ground and Gradients of Main Trunk Pipes,

from

Ullswater and Haweswater to Leeds.

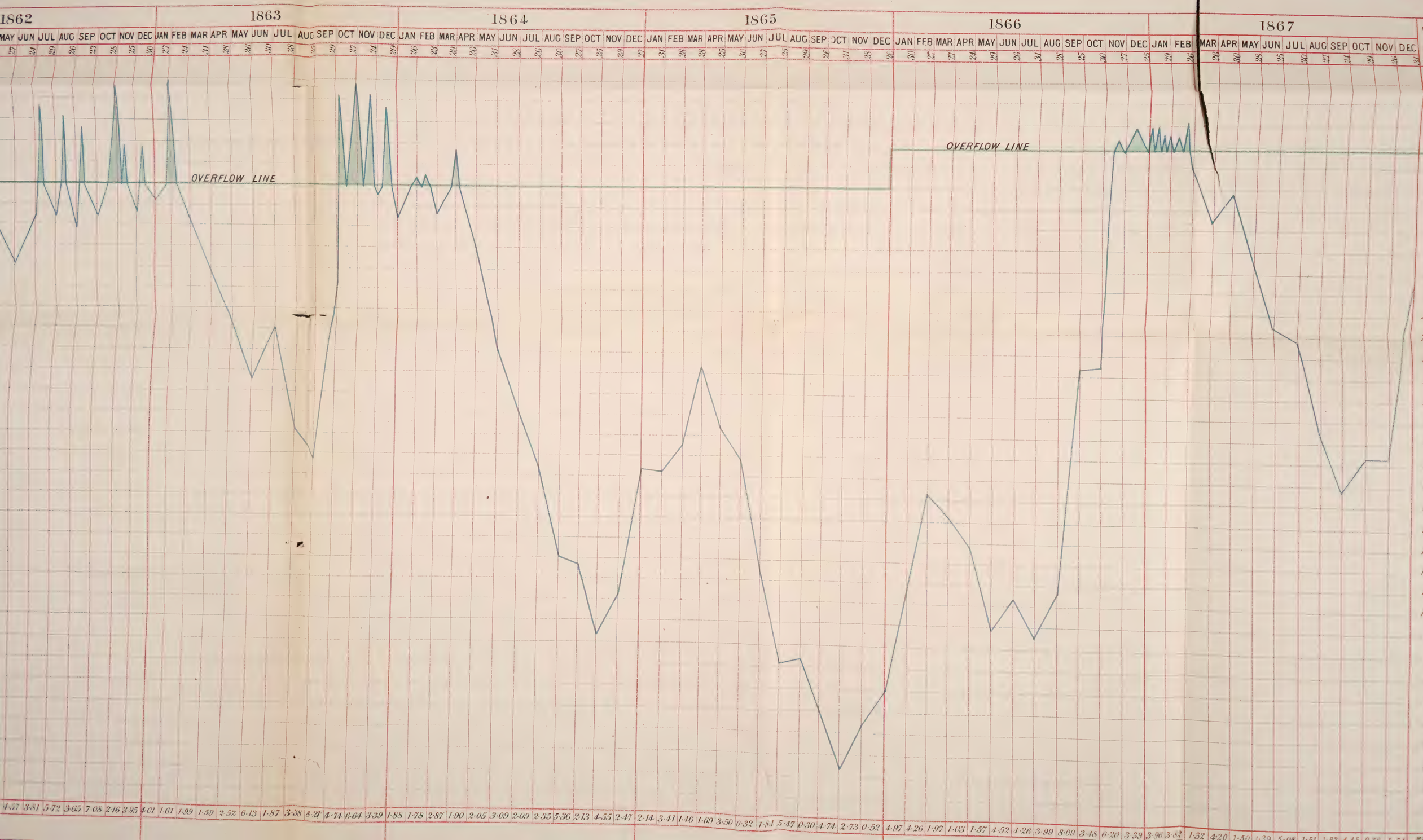


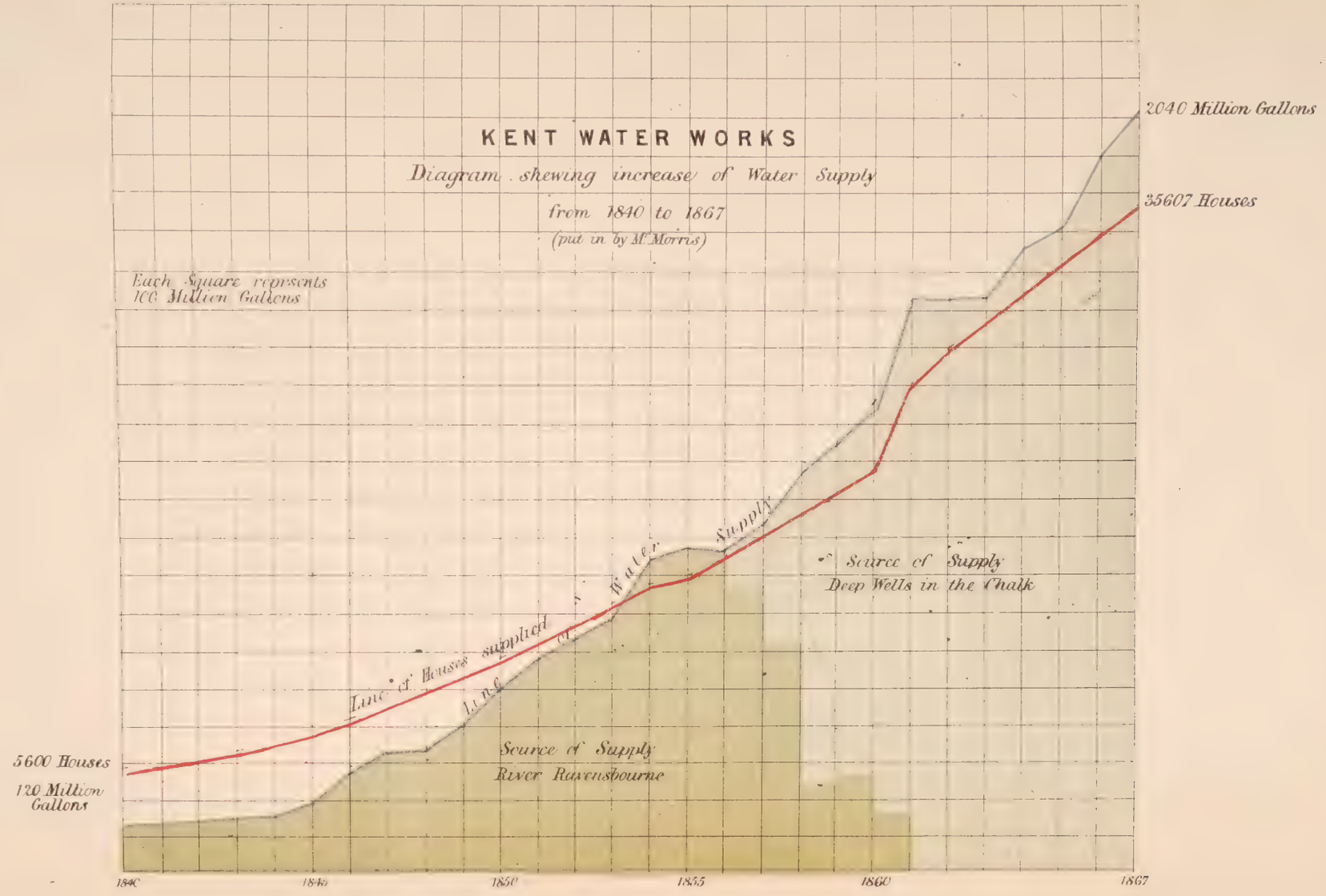
LIVERPOOL CORPORATION WATER WORKS.

DIAGRAM SHEWING RISE AND FALL OF WATER IN STOCK FROM THE YEAR 1862 TO 1867.

(put in by Mr. Duncan.)

Appendix R





Vincent Brooks Day & Son Lith.

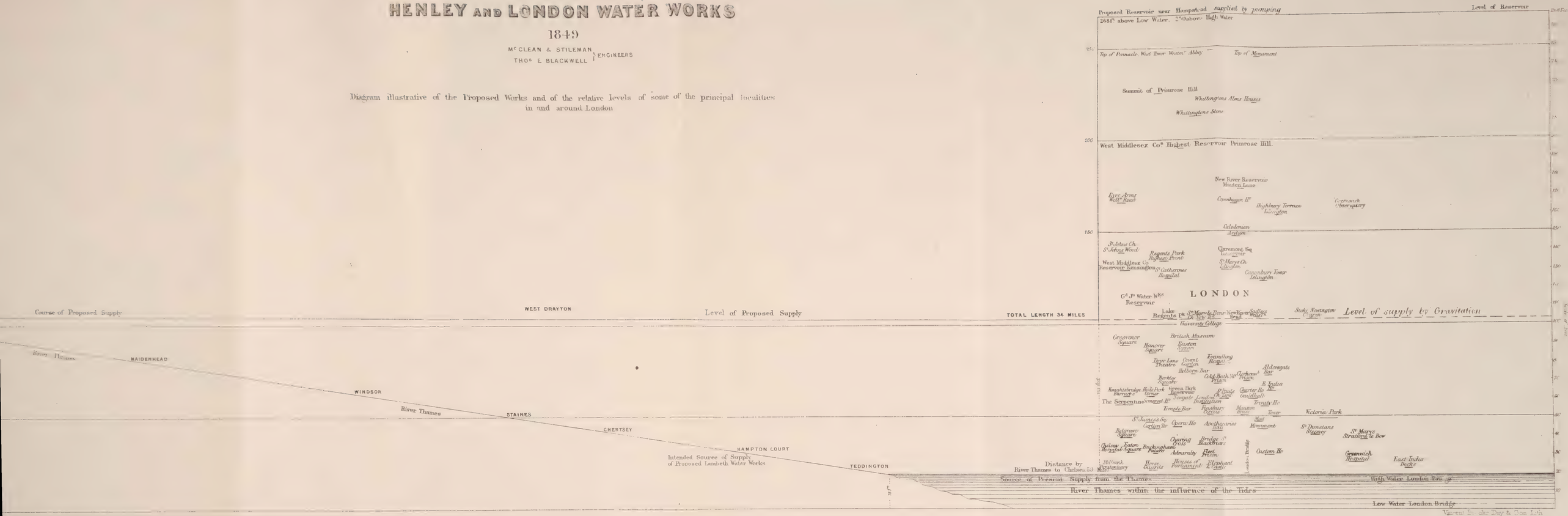
Vincent Brooks Day & Son Lith

HENLEY AND LONDON WATER WORKS

1849

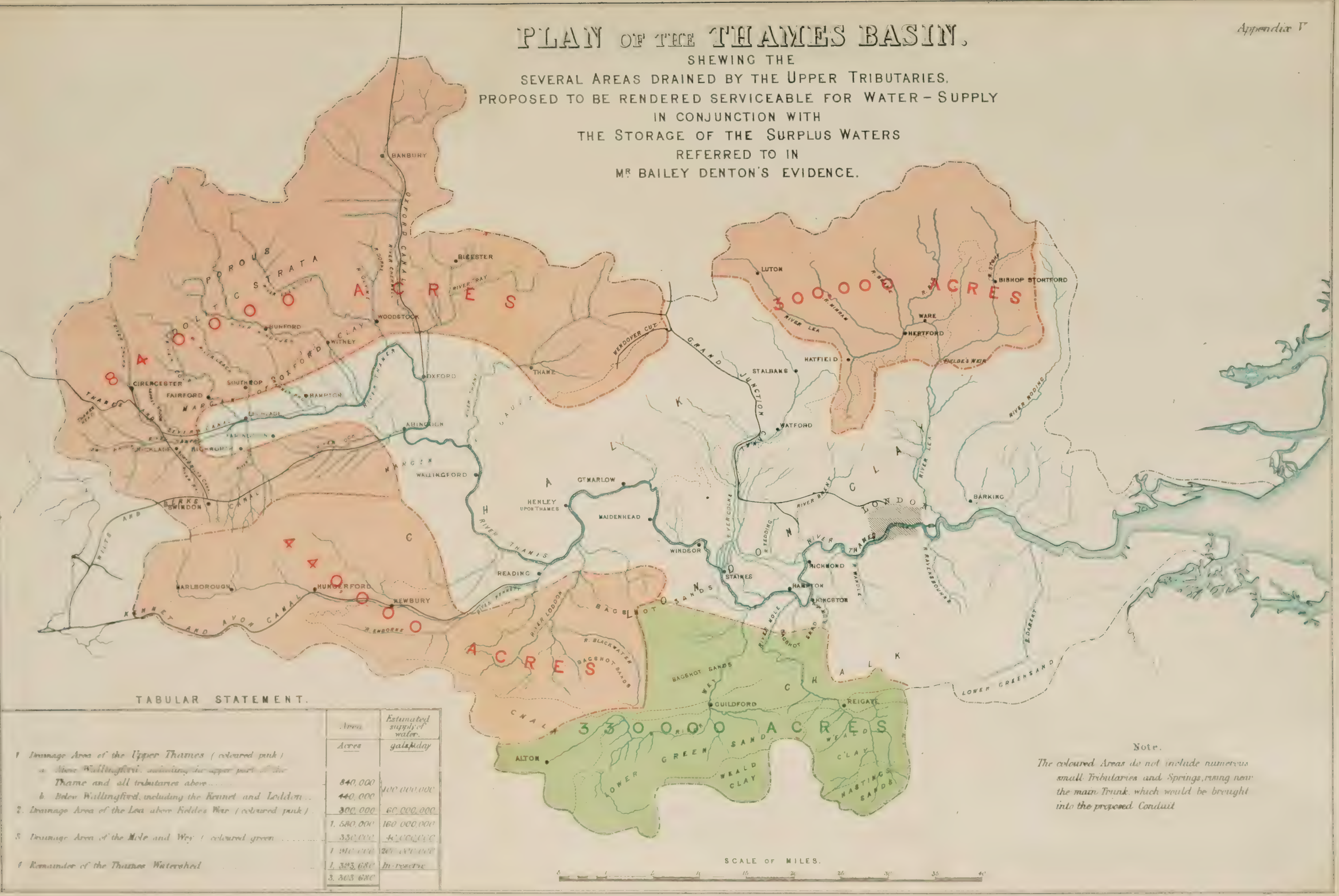
McCLEAN & STILEMAN, THOS E BLACKWELL } ENGINEERS

Diagram illustrative of the Proposed Works and of the relative levels of some of the principal localities in and around London



PLAN OF THE THAMES BASIN.

SHEWING THE
SEVERAL AREAS DRAINED BY THE UPPER TRIBUTARIES,
PROPOSED TO BE RENDERED SERVICEABLE FOR WATER-SUPPLY
IN CONJUNCTION WITH
THE STORAGE OF THE SURPLUS WATERS
REFERRED TO IN
MR BAILEY DENTON'S EVIDENCE.



TABULAR STATEMENT.

	Area	Estimated supply of water.
	Acres	gals/day
1. Drainage Area of the Upper Thames (coloured pink)		
a. Above Wallingford, including the upper part of the Thame and all tributaries above	840,000	100,000,000
b. Below Wallingford, including the Kennet and Loddon	440,000	
2. Drainage Area of the Lea above Edles Weir (coloured pink)	300,000	60,000,000
	1,580,000	160,000,000
3. Drainage Area of the Mole and Wey (coloured green)	330,000	40,000,000
	1,910,000	200,000,000
4. Remainder of the Thames Watershed	1,393,680	In reserve
	3,303,680	

Note.

The coloured Areas do not include numerous small Tributaries and Springs, rising near the main Trunk, which would be brought into the proposed Conduit

MANCHESTER CORPORATION WATER WORKS.

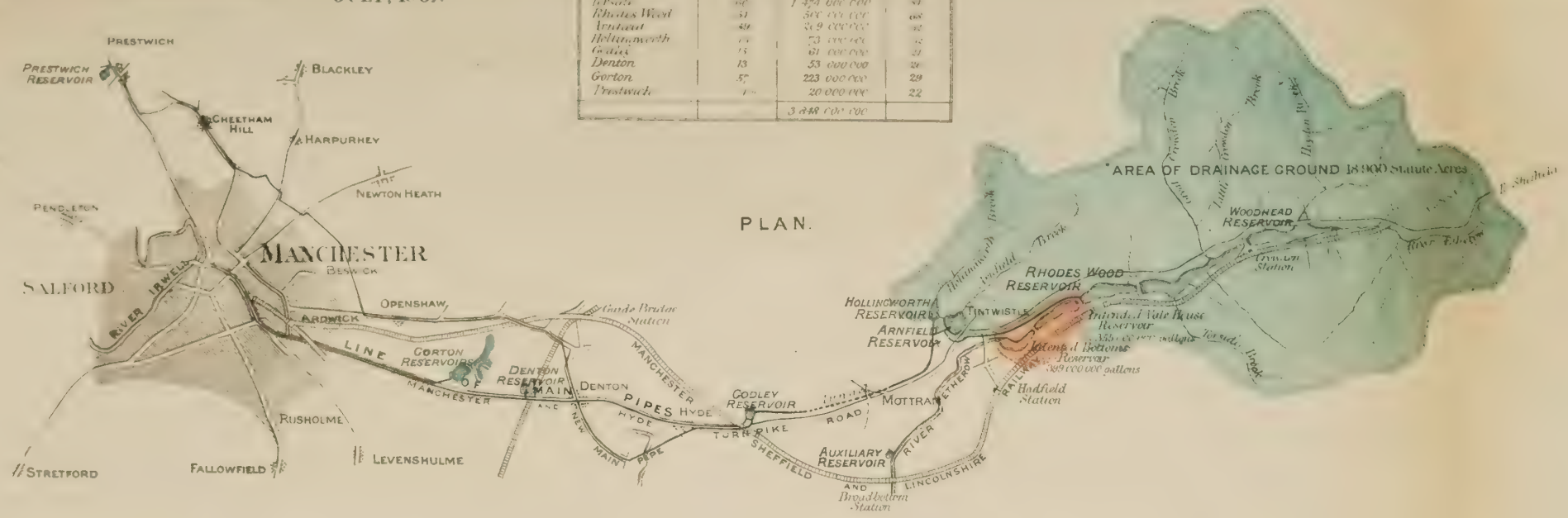
Put in by Mr. Heron

JULY, 1867.

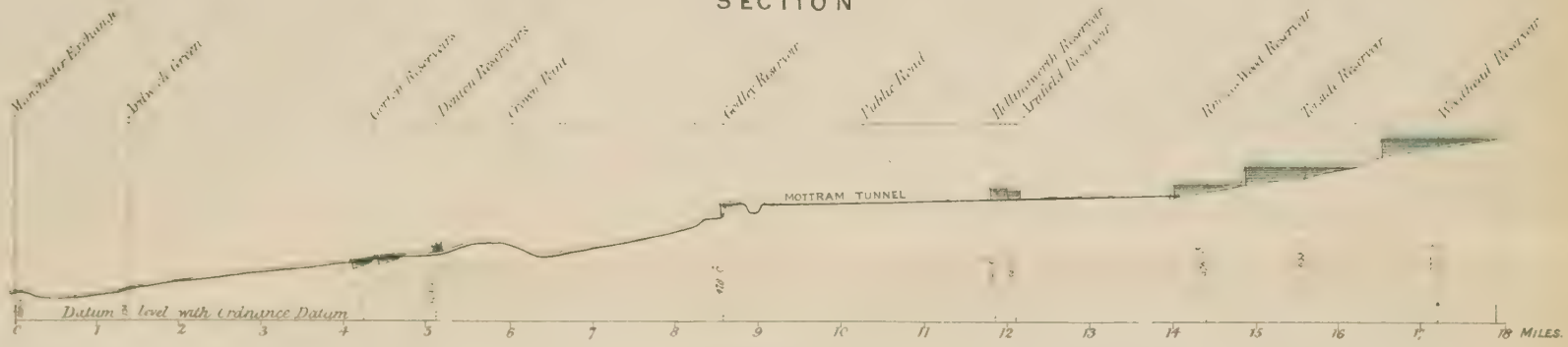
RESERVOIRS AND MAINS.

RESERVOIRS			
NAME	AREA Acres	CAPACITY. Gallons	DEPTH Feet
Woodhead	130	1 230 000 000	72
Torside	60	1 474 000 000	81
Rhodes Wood	51	500 000 000	68
Arnfield	49	309 000 000	42
Hollingworth	17	73 000 000	15
Godley	15	61 000 000	21
Denton	13	53 000 000	20
Gorton	57	223 000 000	29
Prestwich	7	20 000 000	22
		3 848 000 000	

PLAN.



SECTION



SCALES

HORIZONTAL

Furlongs 0 0 1 2 3 4 5 MILES

100 0 100 200 300 400 500 600 700 800 900 1000 FEET

VERTICAL

GEOLOGICAL SECTION ALONG THE LINE OF RAILWAY NEAR CIRENCESTER

(PUT IN BY Mr BRAVENDER)

PLAN PROPOSED BY Mr R.W. MYLNE,

FOR INCREASING THE SUPPLY OF WATER

FROM THE BASIN OF THE RIVER LEA.

Scale One Inch to a Mile.

WEST

Hammersmith

Wandsworth

Clapham

Dulwich

Sydenham

Greenwich

L O N D O N

CHELSEA, WEST MIDDLESEX AND GRAND JUNCTION DISTRICTS

DEPTFORD & VAUXHALL AND LAMBETH DISTRICTS

NEW RIVER AND EAST LONDON DISTRICTS

NEW RIVER HEAD

Kilburn

Hampstead

Highgate

Hornsey

Edgware

River Brent

BRENT RESERVOIR 114 222 ACRES

Contour of 200 ft above Trinity High Water Mark

Reservoirs

Muswell Hill

Stoke Newington Reservoirs

IRON PIPE TO STAMFORD HILL

IRON PIPE FROM HIGH LEVEL RESERVOIR

INTENDED RAILWAY

New River

56 SQUARE MILES

Stamford Hill

Tottenham

Edmonton

Enfield

13 MILES

LEA BRIDGE

E.L.C.C.O. INTAKE

E.L.C.C.O. RESERVOIRS

Lock

Old Ford

LEA AND STORT NAVIGATION

River Lea

PONDERS END 483 SQUARE MILES

Ponders End

Enfield Highway

Cheshunt Street

Waltham Cross

GREAT EASTERN RAILWAY

Wormley

Broxbourne

River Lea

Barnet

East Barnet

Trent Park

Southgate

Enfield Chase

Northaw

Margin of the London Clay

ISOLATED CATCHMENT BASIN

23 SQUARE MILES

GREAT NORTHERN RAILWAY

CATCHING GROUND 7 SQUARE MILES

TUNNEL & COVERED CHANNEL

67 SQUARE MILES

LONDON WATER SUPPLY.

PLAN OF PROPOSED GATHERING GROUNDS, IN THE BASIN OF THE RIVER WYE.

1867.

by Hamilton H. Fulton.

PLYNLUMON FAWR

LLANIDLOES

Pant-mawr Lead Mine

PROPOSED RESERVOIR

MANCHESTER & MILFORD Rly

MID-WALES RAILWAY

Llangurig

RIVER WYE

AUTHORISED RAILWAY

PROPOSED RESERVOIR

AFON MARTEG

Llanidloes

AFON ELAN

St Harmon

Nº 1.

AREA OF WATERSHED 93,752 ACRES OR 146 SQUARE MILES

Daily available Supply 175,000,000 Gallons ¼ or 45,000,000 for Compensation & 131,000,000 for London.

Nº 2.

AREA OF WATERSHED 80,181 ACRES OR 125 SQUARE MILES

Daily available Supply 150,000,000 Gallons ¼ or 38,000,000 for Compensation & 112,000,000 for London.

PROPOSED RESERVOIR

RHAYADER GWY

PROPOSED RESERVOIR

AFON CLAEDWEN

PROPOSED RESEROIR

PROPOSED RESERVOIR

DULAS RIVER

DDOC RIVER

ARAN RIVER

AQUEDUCT DIVERSION

RIVER WYE

RIVER IRFON

Llanladarn fynydd

Pen-y-bont

Llandegley

PROPOSED RESERVOIR

Llandrindod

Howey

Nant-y-car Lead Mine

Newbridge

RIVER DULAS

RIVER CHWEFRU

Nº 3.

AREA OF WATERSHED 64,903 ACRES OR 102 SQUARE MILES

Daily available Supply 120,000,000 Gallons ¼ or 30,000,000 for Compensation & 90,000,000 for London.

Nº 4.

AREA OF WATERSHED 42,925 ACRES OR 67 SQUARE MILES

Daily available Supply 80,000,000 Gallons ¼ or 20,000,000 for Compensation & 60,000,000 for London.

RIVER YRFON

BUILTH

Llanwrtyd

Llangammarch

CENTRAL WALES RAILWAY

RIVER EDW

Abercdw

LONDON WATER SUPPLY.

PLAN SHEWING THE PROPOSED LINE OF AQUEDUCT .

FROM THE BASIN OF THE RIVER WYE TO LONDON.

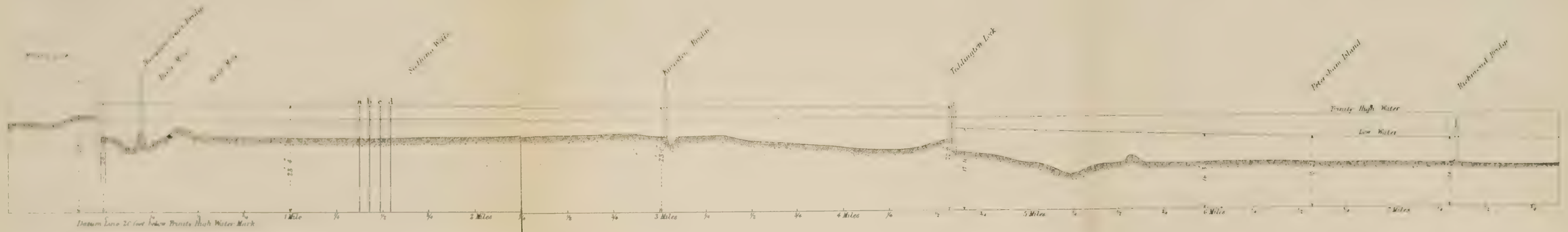
1867.

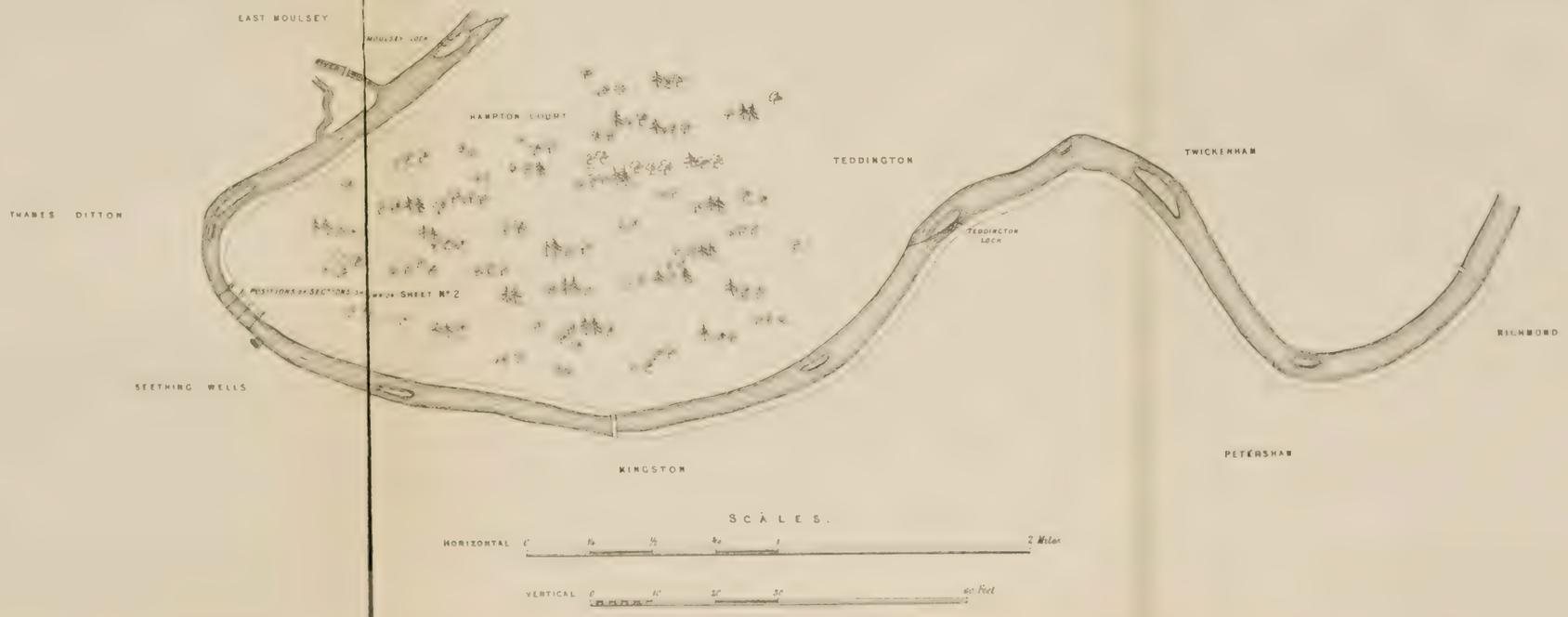
by Hamilton H. Fulton.

Plan and Section furnished by James Simpson Esq^re C.E. and referred to in the evidence of John T. Harrison Esq^re

PLAN AND LONGITUDINAL SECTION OF THE RIVER THAMES FROM MOULSEY LOCK TO RICHMOND BRIDGE

(taken in 1852.)





SCALES.

HORIZONTAL 0 ¼ ½ ¾ 1 2 Miles

VERTICAL 0 15' 25' 30' 60 Feet

Nº2.

Sections furnished by James Simpson Esq.re C.E.
and referred to in the evidence of
John T. Harrison Esq.re

SECTIONS OF THE RIVER THAMES

Taken opposite the Crown & Anchor "P.H." and immediately above the Lambeth Water Works Company's Filters at Ditton.

SCALE 12 FEET TO AN INCH.

NOTE.—A fine Black Line thus _____ indicates the Bed of the River January 1852.
Dotted Black Line thus ..... Dº Dº July 1858.
Full Black Line thus _____ Dº Dº July 1864.

Mean Surface Velocity at Summer Water Level (taken in 1852) 1·25 feet per second.
Dº Dº at 7" below Dº (Dº July 1858) ·75 feet per second.
Dº Dº at 6" below Dº (Dº July 1864) ·80 feet per second.

181 Feet.

SUMMER WATER LEVEL

Area 1153.3 sqr feet
Hyd. mean depth 6.2 ft } taken in 1852.

a.

184 Feet.

SUMMER WATER LEVEL

Area 1185.5 sqr feet
Hyd. mean depth 6.3 ft. } taken in 1852.

b.

187 Feet.

SUMMER WATER LEVEL

Area 1119.2 sqr feet
Hyd. mean depth 5.8 ft. } taken in 1852.

c.

197 Feet.

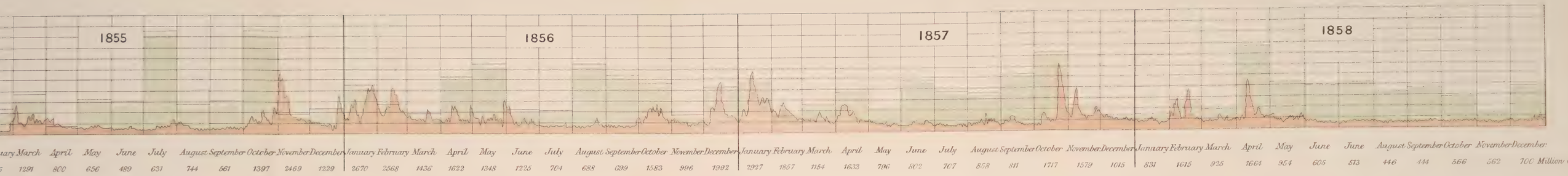
SUMMER WATER LEVEL

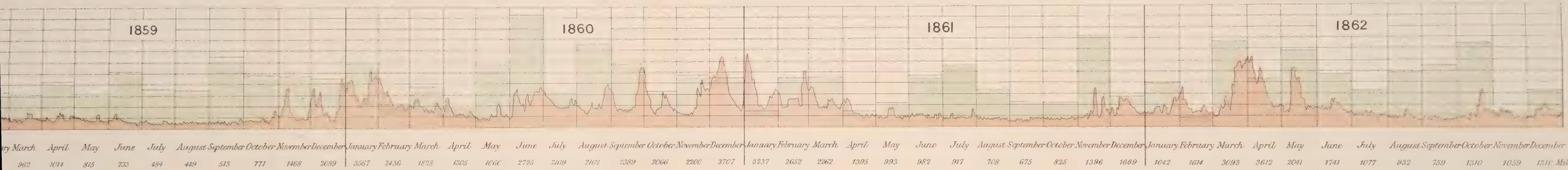
Area 1195.1 sqr feet
Hyd. mean depth 5.83 ft. } taken in 1852.

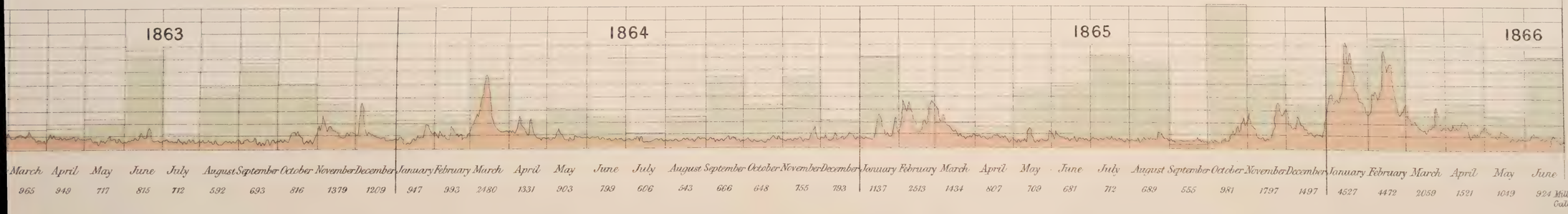
d.

Appendix A.C.

(Referred to in the Evidence of John T. Harrison, Esq.)







DIAGRAM

shewing the average daily rainfall over the

THAMES BASIN

during each month from

JANUARY, 1855 TO JUNE, 1866.

and the volume of water discharged each day at Kingston-on-Thames during the same period.

The Rainfall colored blue.
The Discharge colored red.

Vincent Brooks Day & Son lith.

RIVER THAMES

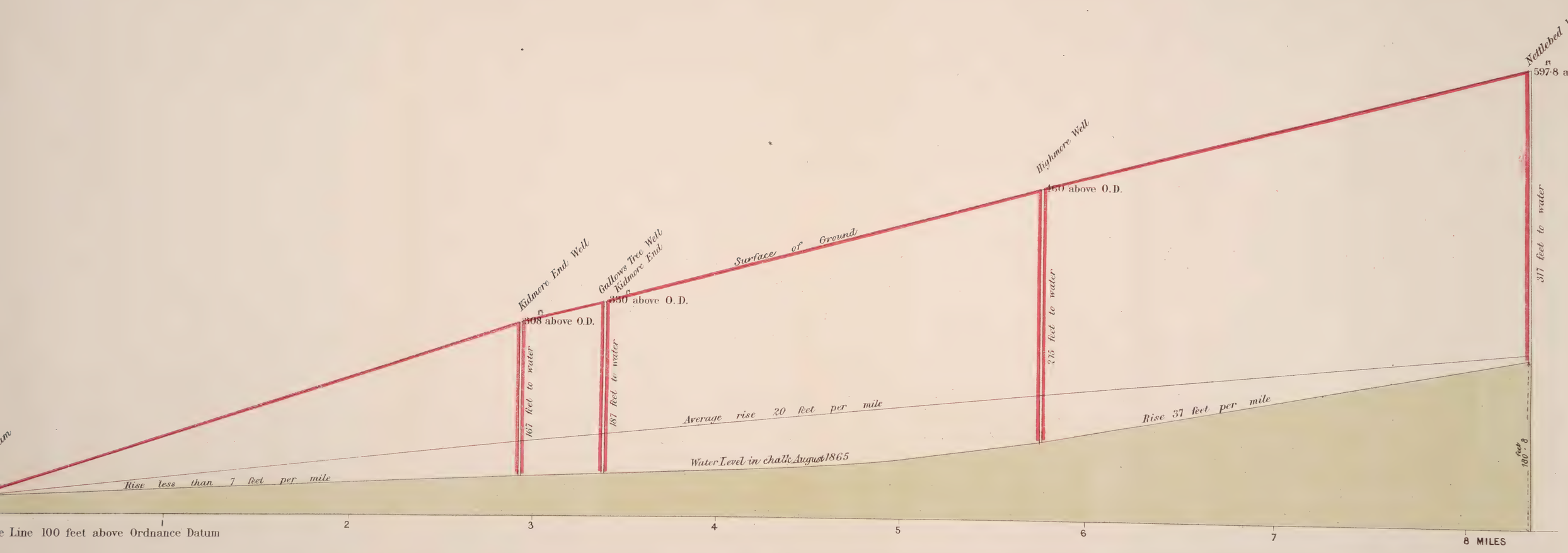
DIAGRAM *shewing the gradual diminution in the Volume of Water discharged by the Thames at Kingston after a heavy general rainfall which thoroughly saturated the Basin supposing no rain to fall subsequently.*

(referred to in the evidence of John T. Harrison Esq.re)

OBSERVATIONS ON WATER LEVEL IN CHALK BETWEEN CAVERSHAM (READING) AND NETTLEBED.

August, 1865.

Referred to in the evidence of John T. Harrison Esq.



APPENDIX AF.

Extract from Report of the Commissioners on the Chemical Quality of the Supply of Water to the Metropolis.—(Parl. Paper, 426, Sess. 1851.)

Specimens of the water of all the companies were taken for analysis, always from a main and generally at the nearest accessible point to the works of the company, or to a distributing reservoir. They were all drawn on the 29th, 30th, and 31st of January last, after moderately rainy weather, with the river full but not flooded. The specimens may be considered as representing the least favourable state of the water supply to the metropolis during winter, but still such as it may continue for several months in a wet season like the last. The temperature of the river at the time was 44° Fahrenheit.

The results are given in two forms, first the acids and bases separately, as actually found by analysis, and secondly the same acids and bases arranged in the form of salts, or chemically combined as they are believed to exist in the waters.

The first group consists of waters not derived from the Thames.

1. *Analyses of the New River, East London, Kent, and Hampstead Waters.*

	New River Water Company.	East London Water Company.	Kent Water Company.	Hampstd. Water Company.
	Grains in an Imperial Gallon.			
Lime	5·7192	6·9034	8·4931	2·9160
Magnesia	0·5280	0·7336	1·6537	1·7098
Potassium	0·4972	0·5600	0·5486	1·6471
Sodium	1·1634	0·9989	1·3790	7·5761
Iron, alumina, and phosphates	trace	0·4760	trace	trace.
Sulphuric acid (SO_3)	3·2550	2·5830	6·8180	9·1702
Chlorine	1·0500	1·0682	2·3387	4·1230
Carbonic acid	11·1020	11·4527	9·8280	10·9823
Silica	0·5005	0·6216	0·7679	0·0728
Nitric acid	0·0150	0·4800	0·0470	0·050
Ammonia	trace	trace	trace	trace.

2. *Analyses of the New River, East London, Kent, and Hampstead Waters.*

	New River Water Company.	East London Water Company.	Kent Water Company.	Hampstd. Water Company.
	Grains in an Imperial Gallon.			
Carbonate of lime	7·82	10·16	7·02	4·95
Sulphate of lime	3·23	2·33	11·03	„
Nitrate of lime	0·02	0.72	0·07	0·07
Carbonate of magnesia	1·09	1·51	3·42	3·53
Chloride of sodium	1·73	1·76	3·50	6·79
Sulphate of soda	1·40	0·94	„	15·14
Chloride of potassium	„	„	0·44	„
Sulphate of potassa	1·11	1·25	0·70	1·40
Carbonate of potassa	„	„	„	1·80
Silica	0·50	0·62	0·76	0·07
Iron, alumina, and phosphates	traces	0·47	traces	traces.
Ammonia	traces	traces	traces	traces.
Organic matter	2·79	4·12	2·61	1·84
Total	19·78	23·88	29·55	35·59
Solid residue obtained on evaporation	19·50	23·51	29·71	35·41
Free carbonic acid in cubic inches at 44° F.	14·49	12·38	10·15	13·30
Free carbonic acid grs. in a gallon	7·24	6·19	5·07	6·67
Suspended matter	1·49	1·07	„	0·52
Degree of hardness (Clerk's scale)	14°9	15°·0	16°·0	9°·8

The second Group is composed of Thames water.

1. *Analyses of Thames Waters.*

	Water taken at Thames Ditton.	Grand Junction Company, supplied at Kew.	West Middlesex Company, supplied at Barnes.	Chelsea Company, supplied at Red House, Battersea.	Southwark and Vauxhall Company, supplied at Red House, Battersea.	Lambeth Company, supplied at Lambeth.
	Grains in the Imperial Gallon.					
Lime	8·0046	7·4522	7·5390	7·5117	7·2751	6·7970
Magnesia	0·6070	0·5544	0·5628	0·5527	0·6020	0·7011
Potassium	0·4261	0·2769	0·2185	0·2821	0·6048	0·4291
Sodium	0·4330	0·6127	0·7387	0·5784	0·7861	0·7805
Iron, alumina, and phosphates	0·0940	0·7630	0·7630	0·2912	0·3430	0·8505
Sulphuric acid	1·8782	2·6460	3·0380	3·3005	2·4150	2·2015
Chlorine	0·9890	0·8512	1·1424	1·2229	1·1725	1·1746
Carbonic acid	14·2170	11·9826	10·6260	10·6470	12·1100	12·8520
Silica	0·6290	0·4466	1·0013	0·7189	0·7679	1·0451
Nitric acid	0·0180	trace	trace	trace	0·2360	trace.
Ammonia	trace	trace	trace	trace	0·0309	trace.

2. *Analyses of Thames Waters.*

	Grains in the Imperial Gallon.					
Carbonate of lime	11·79	10·90	9·94	9·28	10·57	8·99
Sulphate of lime	3·06	3·26	4·78	5·61	3·05	2·99
Nitrate of lime	0·27	trace	trace	trace	0·35	trace.
Carbonate of magnesia	1·27	1·17	1·16	1·08	1·29	1·44
Chloride of sodium	1·10	1·40	1·88	1·47	1·90	1·95
Sulphate of soda	—	0·18	—	—	—	—
Chloride of potassium	0·67	—	—	0·55	—	—
Sulphate of potassa	0·17	0·61	0·48	—	1·34	0·95
Silica	0·62	0·44	1·00	0·71	0·76	1·04
Iron, alumina, and phosphates	0·09	0·67	0·76	0·29	0·34	0·85
Ammonia	trace	trace	trace	trace	0·03	trace.
Organic matter	2·29	3·07	2·75	2·38	1·51	2·59
Total	21·33	21·70	22·75	21·37	21·23	20·80
Solid residue found on evaporation	20·78	21·72	22·67	21·28	21·08	20·40
Free carbonic acid in cubic inches, at 44° F.	16·89	13·46	11·56	12·30	13·57	16·64
Free carbonic acid, grains in gallon	8·25	6·73	5·78	6·15	6·78	8·32
Suspended matter	—	0·01	0·02	—	1·92	1·15
Degree of hardness (Clark's scale)	14·22	14·00	14·60	14·44	15·00	14·16

The waters were all sensibly tinged of a yellow or ochry tint, due chiefly to suspended clay, with the exception of the Kent water, which was clear and bright. This turbid condition of the waters was represented to us as having subsisted for two months, but was rather on the decline at the time of observation. It was least marked in the Chelsea, Grand Junction, and West Middlesex Waters, which are filtered by the companies. These waters did not allow the suspended matter to fall entirely on standing in a glass jar, but remained sensibly coloured after several weeks of rest; they might all, however, we believe, be perfectly clarified by the use of a properly constructed house-filter. The Thames Ditton water was taken from a main in Surbiton, near the company's works, at a later period of the season than the others, namely, on the 22d of February, and was clear and bright. It is a filtered water.

The soluble organic matter from two of the Thames waters was submitted to ultimate analysis, and found to give 0·105 grain of nitrogen in the Grand Junction water, and 0·031 grain of nitrogen in the Southwark and Vauxhall water. The existence of nitrogen is generally supposed to imply the animal origin of organic matter, and on such evidence a minute and probably unimportant portion of animal organic matter would be admitted to be present.

None of the waters had marked taste or odour, nor betrayed any indication of putrescence, either when first taken up or after being kept in bottles for several weeks at a temperature between 50° and 60°; nor even after remaining in close vessels for two weeks at 80°.

In these waters when submitted to microscopic examination no animalcules were observed in any case. But the period of the year was not that at which any considerable development of animal life is to be looked for.

All the waters under consideration have much of a common character, arising from the similar geological conditions of their sources. Every one of them is derived in a great proportion from the chalk formation, of which the waters have peculiar properties. This appears, both in the degree and the nature of the hardness they exhibit, which is due to the presence of salts of lime and magnesia in solution.

APPENDIX A G.

Analyses of Metropolitan Waters, by Drs. Letheby and Odling and Professor Abel, 1867.

Table 1.—General Properties of the Waters supplied by the Metropolitan Water Companies in 1867, before and after Filtration at the Works.

	From Thames at Waterworks above Hampton.	West Middlesex (Thames).		Grand Junction (Thames).		Southwark and Vauxhall (Thames).		Lambeth (Thames).		Chelsea (Thames).		New River (Lea, Springs, and Wells).		East London (Lea).	
		Unfiltered from Works.	From Main.	Unfiltered from Works.	From Main.	Unfiltered from Works.	From Main.	Unfiltered from Works.	From Main.	Unfiltered from Works.	From Main.	Unfiltered from Works.	From Main.	Unfiltered from Works.	From Main.
Date when taken	Feb. 16, 1867.	Jan. 26, 1867.	Jan. 29, 1867.	Feb. 2, 1867.	Feb. 5, 1867.	Feb. 9, 1867.	Feb. 11, 1867.	Dec. 1, 1866.	Dec. 8, 1866.	Dec. 1, 1866.	Dec. 8, 1866.	Jan. 19, 1867.	Jan. 21, 1867.	Jan. 12, 1867.	Jan. 14, 1867.
Hardness (degrees)	14·5	13·0	13·5	13·5	13·0	14·3	13·2	15·5	13·5	15·5	13·5	13·5	13·0	14·4	14·0
Do. after boiling	4·8	4·8	4·0	5·0	5·0	5·5	5·2	5·8	4·3	5·6	4·6	4·2	4·0	5·0	5·0
Dissolved Gases, per Gallon (cub. in.)	13·70	13·50	13·54	12·99	12·81	13·00	14·95	14·63	13·93	14·71	14·00	13·95	12·75	12·51	13·75
Consisting of (per cent.) Carbonic Acid	46·85	34·58	46·12	38·69	42·58	46·92	37·79	48·16	38·26	49·67	41·90	41·21	35·29	37·50	41·82
Oxygen	15·75	19·58	16·97	16·76	16·41	15·39	16·72	16·36	18·91	16·46	18·11	19·00	20·78	20·83	15·99
Nitrogen	37·40	45·84	36·91	44·55	41·01	37·69	45·49	35·48	42·83	33·87	39·99	39·79	43·93	41·67	42·19
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Oxygen required to oxydise—															
(*a*) Nitrate and Protosalt Iron	0·070	0·000	0·000	0·100	0·030	0·070	0·050	0·000	0·070	0·000	0·000	0·000	0 000	0·000	0·017
(*b*) Organic Matter	0·110	0·115	0·075	0·125	0·135	0·100	0·110	0·110	0·095	0·110	0·105	0·115	0·069	0·090	0·078
Total per Gallon (grains)	0·180	0·115	0·075	0·225	0·165	0·170	0·160	0·110	0·165	0·110	0·105	0·115	0·069	0·090	0·095
Oxygen dissolved in the water (grains)	0·738	0·904	0·786	0·745	0·719	0·684	0·855	0·819	0·901	0·828	0·867	0·906	0·906	0·891	0·752
Ammonia, per Gallon (grains)	0·003	0·003	0·001	0·003	0·002	0·002	0·002	0·003	0·002	0·005	0·002	0·001	0·001	0·004	0·003

General Results.	Thames Companies.		New River.		East London.	
	Unfiltered.	Filtered.	Unfiltered.	Filtered.	Unfiltered.	Filtered.
Hardness before Boiling (degrees)	14·4	13·3	15·5	13·5	14·4	14·0
Do. after do. do.	5·3	4·6	4·2	4·0	5·0	5·0
Dissolved Gases, per Gallon (cubic inches)	13·77	13·85	13·95	12·75	12 51	13·75
Dissolved Oxygen, do. (grains)	0·796	0·825	0·906	0·906	0·891	0·752
Oxygen required to oxydise Organic and other Matter (grs.)	0·146	0·134	0·115	0·069	0·090	0·095
Ammonia, per Gallon (grains)	0·003	0·002	0·001	0·001	0·004	0·003

All the samples of Filtered Water drawn from the Mains were clear, and when examined in a glass tube two feet in length, they had only a very pale greenish yellow tinge. Judging from this, and from the small amount of oxygen required to oxydise the organic matter, it could not in any case have exceeded a grain per gallon of water, or one part in seventy thousand parts.

The proportion of ammonia was also very small—the range being from the 1-1,000th of a grain per gallon of water, to the 4-1,000th of a grain per gallon—that is, from one part of ammonia in seventy million parts of water to one part in seventeen and a half millions.

TABLE 2.—ANALYSES of the WATERS supplied by the METROPOLITAN WATER COMPANIES in 1867, before and after FILTRATION at the WORKS.

	Thames, at Waterworks above Hampton.	West Middlesex (Thames).		Grand Junction (Thames).		Southwark and Vauxhall (Thames).		Lambeth (Thames).		Chelsea (Thames).		New River (Lea, Springs, and Wells).		East London (Lea).	
		Unfiltered from Works.	From Mains.	Unfiltered from Works.	From Mains.	Unfiltered from Works.	From Main.	Unfiltered from Works.	From Main.	Unfiltered from Works.	From Main.	Unfiltered from Works.	From Main.	Unfiltered from Works.	From Main.
Date when taken	Feb. 16, 1867.	Jan. 26. 1867.	Jan. 29, 1867.	Feb. 2, 1867.	Feb. 5, 1867.	Feb. 9, 1867.	Feb. 11, 1867.	Dec. 1, 1866.	Dec. 8, 1866.	Dec. 1, 1866.	Dec. 8, 1866.	Jan. 14, 1867.	Jan. 21, 1867.	Jan. 12, 1867.	Jan. 14, 1867.
	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
Lime	8·710	8·093	8·664	8·030	8·070	8·273	8·213	8·653	7·142	8·644	7·273	8·104	9·129	10·533	10·300
Magnesia	0·548	0·445	0·475	0·705	0·728	0·529	0·525	0·448	0·468	0·566	0·551	0·530	0·449	0·592	0·543
Potassa	0·432	0·451	0·368	0·472	0·421	0·455	0·373	0·399	0·452	0·435	0·381	0·290	0·397	0·454	0·434
Soda	1·035	1·003	0·858	1·190	1·084	0·960	1·204	0·975	1·212	0·952	1·204	0·876	0·825	1·006	1·137
Ammonia	0·003	0·003	0·001	0·003	0·002	0·002	0·002	0·003	0·002	0·005	0·002	0·001	0·001	0·004	0·003
Iron and Alumina	0·073	0·126	0·004	0·298	0·168	0·160	0·087	0·018	0·331	0·038	0·180	0·203	0·029	0·205	0·068
Carbonic Acid	5·357	5·305	5·493	4·746	4·996	5·202	5·111	5·831	4·868	5·797	4·306	7·485	6·165	7·164	6·883
Sulphuric Acid	1·130	0·990	0·930	1·640	1·540	1·500	1·510	1·060	1·440	1·510	1·510	0·810	0·790	1·610	1·650
Nitric Acid	0·731	0·989	0·864	0·724	0·768	0·800	0·847	0·916	0·754	0·918	0·892	0·684	0·790	0·800	0·796
Chlorine	0·990	0·980	0·980	1·060	1·020	1·050	1·000	1·020	1·020	1·100	1·030	0·950	0·950	1·220	1·100
Silica	0·253	0·440	0·113	0·493	0·453	0·440	0·480	0·730	0·331	0·544	0·456	0·768	0·702	0·490	0·747
Total	19·262	18·825	18·750	19·361	19·250	19·371	19·352	20·053	18·020	20·509	17·785	20·701	20·227	24·078	23·661
From which the Oxygen equivalent of Chlorine is to be deducted	0·220	0·218	0·218	0·234	0·227	0·233	0·222	0·227	0·227	0·244	0·229	0·211	0·211	0·271	0·244
Total Saline Matter, per gallon	19·042	18·607	18·532	19·127	19·023	19·138	19·130	19·826	17·793	20·265	17·556	20·490	20·016	23·807	23·417
Organic and other Volatile Matter determined by Incineration	0·892	1·327	0·462	1·497	1·188	1·078	1·010	1·217	1·235	1·187	0·985	0·702	0·567	0·915	0·300
Total Solid Matter obtained by Analysis	19·934	19·934	18·994	20·624	20·211	20·216	20·140	21·043	19·028	21·452	18·541	21·192	20·583	24·722	23·717
Do. do. by Evaporation	20·577	19·830	19·683	20·862	19·968	20·833	20·024	21·425	18·783	21·173	18·937	22·402	21·550	24·940	24·360
Suspended Matter: Organic	0·140	0·101	0·009	0·275	0·000	0·201	0·005	0·100	0·005	0·186	0·007	0·033	0.014	0·045	0·023
Suspended Matter: Mineral	1·089	0·415	0·028	1·304	0·005	1·086	0·019	0·224	0·038	0·260	0·053	0·208	0·081	0·516	0·024
Total per Gallon	1·229	0·516	0·037	1·579	0·005	1·287	0·024	0·324	0·043	0·446	0·060	0·241	0·095	0·561	0·047

GENERAL RESULTS.	Thames Companies,		New River.		East London.	
	Unfiltered.	Filtered.	Unfiltered.	Filtered.	Unfiltered.	Filtered.
	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
Dissolved Matter, per Gallon	20·825	19·479	22·402	21·550	24·940	24·360
Of which Organic and other Volatile Matter	1·261	0·976	0·702	0·567	0·915	0·300
Suspended Matter, per Gallon	0·830	0·034	0·241	0·095	0·561	0·047
Of which Organic and other Volatile Matter	0·173	0·005	0·033	0·014	0·045	0·023

TABLE 3.—Showing the Variations in the WATERS supplied by the METROPOLITAN WATER COMPANIES during each Month of the Years 1865 and 1866.

1865 and 1866.	Solid Matter, per Gallon.								Organic and other Volatile Matter determined by Incineration.								Oxygen required to oxydise Organic and other Matter, per Gallon.							
	West Middlesex (Thames).	Grand Junction (Thames).	Southwark and Vauxhall (Thames).	Lambeth (Thames).	Chelsea (Thames).	New River (Lea Springs and Wells).	East London (Lea).	Kent (Chalk Wells).	West Middlesex (Thames).	Grand Junction (Thames).	Southwark and Vauxhall (Thames).	Lambeth (Thames).	Chelsea (Thames).	New River (Lea Springs and Wells.)	East London (Lea).	Kent (Chalk Wells).	West Middlesex (Thames).	Grand Junction (Thames).	Southwark and Vauxhall (Thames).	Lambeth (Thames).	Chelsea (Thames).	New River (Lea Springs and Wells).	East London (Lea).	Kent (Chalk Well).
	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
January - -	21·32	20·95	20·73	20·78	21·39	19·28	23·02	25·41	1·55	1·57	1·74	1·45	0·92	1·20	1·73	1·17	0·076	0·095	0·079	0·114	0·118	0·047	0·067	0·026
February - -	21·28	21·09	22·65	20·97	22·10	19·95	22·95	24·44	1·75	1·53	1·79	1·74	2·00	1·20	1·21	1·40	0·073	0·085	0·085	0·101	0·075	0·060	0·072	0·031
March - -	20·36	20·99	20·76	20·39	20·14	20·57	22·52	25·24	1·55	1·50	1·54	1·73	1·48	1·43	1·66	1·58	0·090	0·070	0·081	0·091	0·114	0·045	0·076	0·030
April - - -	18·71	20·43	19·35	19·00	19·19	18·35	20·65	27·11	1·26	1·31	1·31	1·70	1·19	1·08	1·49	1·21	0·075	0·045	0·058	0·060	0·069	0·046	0·058	0·031
May - - -	18·94	19·10	18·53	18·40	19·18	16·82	19·24	25·66	1·57	1·04	1·50	1·57	1·38	0·98	1·04	1·35	0·058	0·040	0·079	0·069	0·067	0·039	0·059	0·018
June - - -	18·02	18·05	18·81	18·60	18·96	16·13	18·25	27·01	0·71	0·67	1·02	0·80	1·18	0·93	1·25	1·25	0·050	0·078	0·081	0·090	0·080	0·049	0·054	0·010
July - - -	16·97	17·50	17·15	18·04	17·55	16·73	17·83	27·28	0·80	1·22	0·92	1·08	1·26	0·94	1·01	1·57	0·095	0·077	0·071	0·085	0·078	0·023	0·044	0·021
August - -	16·80	17·51	17·93	16·98	17·71	16·29	16·99	25·78	0·59	0·90	1·10	1·33	1·00	0·73	1·02	0·98	0·065	0·063	0·080	0·080	0·085	0·046	0·070	0·011
September - -	16·09	18·07	17·16	18·12	18·00	15·84	18·76	25 45	0·83	0·80	0·95	1·01	0·85	0·79	1·26	1·25	0·085	0·073	0·095	0·084	0·061	0·038	0·050	0·033
October - -	18·64	19·00	18·43	19·42	18·51	17·88	18·09	25·39	0·91	0·92	1·07	0·81	0·60	0·65	0·84	1·36	0·081	0·091	0·083	0·070	0·062	0·029	0·058	0·032
November - -	20·15	20·36	20·81	20·28	21·18	20·09	22·39	26·25	0·88	0·88	1·44	1·43	1·12	0·67	0·99	0·58	0·098	0·091	0·169	0·157	0·128	0·082	0·114	0·034
December - -	21·07	20·76	21·64	20·28	20·08	21·09	23·85	26·74	0·96	1·14	1·68	1·23	1·12	0·70	1·21	0·79	0·083	0·111	0·183	0·136	0·119	0·080	0·125	0·011
Yearly Average -	19·03	19·48	19·50	19·27	19·50	18·25	20·38	25·98	1·11	1·12	1·34	1·32	1·17	0·94	1·23	1·21	0·077	0·077	0·095	0·095	0·088	0·049	0·071	0·024

These results are the averages of the corresponding months in the two years (1865 and 1866), and they show that, in the case of the Thames and River Lea, the *maximum* amount of solid matter is found in the water during the winter months, when the rainfall is greatest and the evaporation least; and the *minimum* amount of solid matter is found in the water in the months of July, August, and September, when the rainfall is least and the evaporation greatest.

TABLE 4.—COMPARISON of the QUALITY and QUANTITY of WATER supplied by the METROPOLITAN WATER COMPANIES in the Years 1851, 1856, and 1867.

Companies.	Solid Matter, per gallon.			Organic and other Volatile Matter, per gallon.			Degree of Hardness.			Quantity supplied per Day.		
	1851.	1856.	1867.	1851.	1856.	1867.	1851.	1856.	1867.	1851.	1856.	1867.
	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Degrees.	Degrees.	Degrees.	Gallons.	Gallons.	Gallons.
New River	19·50	21·71	21·55	2.79	0·96	0·57	14·9	13·6	14·0	15,435,617	25,000,000	22,931,917
East London	23·51	21·43	24·36	4·12	1·14	0·30	15·0	14·3	14·5	9,036,049	16,000,000	19,321,988
Thames Companies: Chelsea	21·28	21·85	18·94	2·38	1·21	0·99	14·4	13·3	13·5	3,940,730	5,323,000	7,918,375
Thames Companies: West Middlesex	22·67	20·58	19·68	2·75	1·47	0·46	14·6	14·0	13·2	3,334,054	6,895,368	8,236,882
Thames Companies: Grand Junction	21·72	22·28	19·97	3·07	1·50	1·19	14·0	15·0	13·0	3,541,717	6,714,292	8,709,090
Thames Companies: Southwark and Vauxhall	21·08	20·85	20·02	1·51	1·34	1·01	15·0	13·3	13·2	6,013,716	10,331,122	12,679,311
Thames Companies: Lambeth	20·40	19·65	18·78	2·59	1·03	1·24	14·2	11·7	13·5	3,077,260	6,109,000	8,950,567
Kent	29·71	26·18	27·12	2·61	1·22	0·16	16·0	11·8	16·0	1,079,311	2,363,730	5,927,200
										Total.	Total.	Total.
Average of Thames Companies	21·45	21·04	19·48	2·46	1·31	0·98	14·4	13·5	13·3	19,907,477	36,049,782	46,494,225
Average of New River and East London	21·50	21·57	22·95	3·45	1·05	0·43	14·9	13·9	14·2	24,471,666	41,000,000	42,253,905
Average of all Companies	22·48	21·81	21·30	2·73	1·23	0·74	14·8	13·4	13·9	45,885,925*	78,202,842†	94,675,330

The Returns of 1851 are taken from the Report by the Government Commission on the Chemical Quality of the supply of Water to the Metropolis in 1851; and those of 1856 are taken from the Reports to the Right Hon. William Cowper, M.P., President of the General Board of Health on the Metropolis Water Supply in 1856.

* This total includes 427,468 gallons of water daily, supplied by the Hampstead Company in 1851.

† This total includes 603,060 gallons of water daily, supplied in 1856 by the Hampstead Water Company, and 550,000 gallons supplied in the same year by the Plumstead, Woolwich, and Charlton Water Company.

In 1851 the population of London was 2,362,236; consequently there were 19·4 gallons of water supplied per head of the whole population.
In 1856 " " 2,583,112; " " 30·2 " "
In 1867 " " is 3,067,536; " " are 30·9 " "

TABLE 5.—QUALITY of the WATER supplied to the following TOWNS in ENGLAND.

Name of Town.	Appearance of the Water when Examined in a Glass Tube Two Feet in Length.	Solid Matter per Gallon.	Organic and other Volatile Matter per Gallon.	Oxygen required to oxydise Organic and other Matter.	Ammonia per Gallon.	Hardness.		1861.	
						Before Boiling.	After Boiling.	Population.	Mortality per 1,000 of Population.
		Grains.	Grains.	Grains.	Grains.	Degrees.	Degrees.		
Birmingham	Slightly turbid, and pale olive green	37·70	1·65	0·090	0·020	15·5	11·5	212,621	24·4
Leamington	Slightly turbid, and pale greenish yellow	36·79	1·98	0·185	0·045	18·5	9·0	18,768	18·8
Guildford	Bright and colourless	30·50	2·50	0·075	0·002	18·5	7·8	29,330	19·4
Sunderland and South Shields	Do.	29·75	1·10	0·020	0·001	12·6	8·0	135,553	20·7
Southport	Do.	28·35	2·63	0·075	0·020	19·5	12·5	14,647	19·0
Newcastle and Gateshead	Slightly turbid, and pale greenish yellow	22·53	0·95	0·080	0·019	19·5	5·5	14,646	19·0
Wakefield	Turbid and olive green	22·25	1·34	0·140	0·115	16·0	12·0	55,049	24·8
Dover	Bright and nearly colourless	22·01	1·04	0·005	0·001	17·0	6·5	31,575	24·2
Canterbury	Do. colourless	21·85	1·00	0·007	0·020	18·0	4·5	16,643	21·4
Norwich	Do. nearly colourless	21·19	1·10	0·020	0·025	14·5	5·0	74,440	26·7
Croydon	Do. do.	20·75	0·80	0·020	0·001	16·4	5·1	46,474	17·4
York	Do. do.	19·08	0·80	0·080	0·020	14·3	7·0	59,909	24·0
Derby	Do. do.	19·02	1·06	0·035	0·001	14·4	7·0	51,049	25·3
Lincoln	Do. pale olive green	18·34	1·35	0·078	0·008	11·0	7·5	47,063	20·9
Worcester	Do. pale peaty tint	16·89	1·53	0·106	0·035	10·0	6·0	30,969	20·0
Cheltenham	Do. nearly colourless	15·70	1·06	0·087	0·040	12·0	6·0	49,792	18·9
Liverpool and West Derby	Slightly turbid and peaty	14·64	0·55	0·085	0·030	9·6	3·5	495,587	28·2
Durham	Bright and nearly colourless	13·58	1·01	0·103	0·050	7·5	6·0	70,274	20·7
Leeds	Do. pale olive green	13·37	0·58	0·110	0·040	7·5	6·5	117,566	26·0
Edinburgh	Do. nearly colourless	10·30	0·57	0·060	0·002	7·0	2·0	176,081	27·4
Preston	Turbid and slightly peaty	7·81	0·07	0·145	0·035	5·5	2·9	110,523	28·9
Dundee	Slightly turbid and peaty	7·00	0·50	0·170	0·002	4·3	1·5	—	—
Sheffield	Bright and peaty	5·90	0·50	0·080	0·013	2·0	2·0	128,951	26·2
Glasgow, south of Clyde (Gorbals)	Slightly turbid and peaty	5·94	0·63	0·155	0·028	2·9	1·0	440,979	27·1
Do., north of do. (Loch Katrine	Do. do.	1·90	0·30	0·110	0·032	1·0	1·0		
Plymouth	Bright and rather peaty	4·29	0·41	0·055	0·032	3·0	1·0	62,599	22·1
Manchester and Salford	Do. deep olive green	4·17	0·25	0·125	0·006	2·5	2·0	349,323	28·7
Towns with water over 10 deg. hardness	Bright and nearly colourless	23·90	1·37	0·068	0·028	14·9	7·1	—	22·2
Do. under do. do.	Generally slightly turbid and peaty	8·33	0·49	0·102	0·021	4·9	2·6	—	26·1
Metropolitan water	Bright and slightly greenish yellow	20·17	1·18	0·072	0·002	13·0	4·5	—	23·1

TABLE 6.—COMPOSITION of the WATERS of the PUMPS and SURFACE WELLS of the CITY of LONDON.

Names of Pumps.	Carbonate of Lime and Magnesia.	Sulphate of Lime and Magnesia.	Alkaline Chloride.	Alkaline Nitrate.	Silica and Alumina.	Organic and other Volatile Matter.	Total per Gallon.
	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
Aldgate	23·43	15·63	13·17	19·37	0·96	4·87	77·43
Aldgate High Street	25·30	24·30	20·70	24·20	1·12	8·13	103·75
Bartholomew Lane	21·70	16·17	15·47	16·50	0·97	4·56	75·37
Basinghall Street	21·17	25·20	12·73	13·60	0·97	6·30	79·97
Bell Yard, Gracechurch Street	19·29	12·80	19·11	19·58	1·00	8·22	80·00
Bishopsgate Church	22·60	21·20	18·20	17·33	1·10	6·23	86·66
Bishopsgate Street, by Dunning's Alley	32·23	33·54	22·43	16·06	1·50	9·07	114·83
Bow Churchyard	25·80	19·13	18·47	12·87	1·00	5·43	82·70
Bowling Square	18·67	26·20	11·17	9·13	1·00	4·93	71·10
Bride Lane	14·53	23·07	25·53	24·27	0·93	6·87	95·20
Cannon Street West	14·80	13·73	10·87	25·53	1·00	5·10	71·03
Chequer Yard, Dowgate Hill	20·53	16·43	11·87	16·57	1·03	7·03	73·46
Cock and Hoop Yard, Houndsditch	19·93	17·33	13·03	21·90	1·00	5·60	77·79
Cornhill	22·13	18·20	10·70	16·23	1·20	5·37	73·83
Cree Church Lane	21·07	9·43	6·70	7·17	0·87	2·56	47·80
Fenchurch Street	21·77	20·23	14·50	21·33	0·87	7·23	85·93
Guildhall	12·90	8·65	4·30	3·05	0·95	2·90	32·75
Guildhall Buildings	13.37	4·40	3·40	2·76	0·60	2·10	26·63
Gutter Lane	16·57	15·53	7·47	10·53	0·97	5·33	58·40
Great St. Helen's	15·47	10·83	6·50	12·27	0·76	3·50	49·33
Half Moon Passage	16·40	13·00	17·23	15·00	0·87	3·50	66·00
Herald's College Yard	14·57	21·90	15·87	30·50	0·93	5·86	89·63
Honey Lane Market	16·10	10·50	9·23	6·63	1·10	3·27	46·83
Idol Lane	15·70	19·50	15·73	22·63	1·30	5·44	80·30
Ironmonger Lane	19·27	30.60	13·57	15·07	1·26	6·90	86·67
Leadenhall Market	16·63	23·97	38·60	29·13	1·07	5·53	114·93
Little Britain	25·27	29·93	13·83	6·42	1·43	8·27	85·17
Minories	21·93	21·70	15·46	29·00	1·23	6·63	95·97
Milton Street, Cripplegate	33·63	37·84	22·93	23·50	1·33	8·34	127·57
Mitre Square	17·23	10·33	7·27	6·03	0·97	4·37	46·20
Newgate Market	19·73	14·14	13·70	14·70	1·30	6·83	70·40
Old Jewry	18·50	15·20	7·70	13·33	0 94	4·93	60·27
St. Mary Axe	23·47	19·93	12·57	20·74	1·13	5·53	83·37
St. Nicholas Olave Churchyard	21·03	29·17	31·87	38·36	1·20	8·10	129·73
St. Paul's Churchyard	20·60	15·20	9·47	20·80	1·10	4·10	71·27
East London Water Company	13·08	3·33	1·36	2·07	0·47	0·56	20·87
New River Water Company	12·58	2·41	1·28	2·08	0·38	0·32	19·05
Thames Companies	11·91	2·36	2·01	2·16	0·52	0·84	19·80

APPENDIX AH.

REPORT on the QUALITY of the WATERS supplied by the METROPOLITAN WATER COMPANIES in May, June, and July, 1868, with Tables and Analyses.

To James Simpson, Esq.

SIR,

IN accordance with your instructions of the 18th of May last, on behalf of the several Metropolitan Water Companies, to the effect that we would collect and analyze samples of the water supplied by them in 1868, and report to you thereon, we have now to submit a Tabular Statement of the analytical results arrived at by us (vide appended Tables Nos. 1 and 2) in the examination of samples collected at the following under-mentioned places:

At the Cab-rank, Portland Road, from main of West Middlesex Company.

At the Cab-rank, Piccadilly, from main of Grand Junction Company.

At the Cab-rank, St. George's Church, from main of Southwark and Vauxhall Company.

At the Cab-rank, Lambeth Baths, from main of Lambeth Company.

At the Cab-rank, Whitehall, from main of Chelsea Company.

At Public Tap, Aldgate, from main of New River Company.

At London Hospital, from main of East London Company.

At New Cross, from main of Kent Company.

1. On reference to table No. 1, it will be observed that the hardness of the water supplied by the Thames Companies ranges from 11·3° to 12·5°—that from the New River being 11·0°; while the water from the East London Company has a hardness of 11·7°; and that of the Kent Company a hardness of 17·6°.

After boiling for fifteen minutes, the hardness of the water from the Thames Companies is reduced to between 2·4° and 3·5°; the New River water to 2·3°; the East London water to 2·6°; and the Kent Company's water to 6°.

On comparing these results with the return of analyses made by us in the winter of 1866–7 (in reference to the Metropolis Water Inquiry, conducted by a Committee of the House of Commons in 1867) it will be observed that, in all instances, excepting that of the Kent Company's water (derived solely from deep wells) the hardness is less than that of the water collected during the winter season, a result which is in accordance with previous experience regarding the fluctuations in the composition of river water at different seasons.

2. The total proportion of dissolved gases is, as might have been anticipated, a little lower than in the colder season; but it is observable that the amount of carbonic acid in the water is somewhat higher than it was in the winter, the nitrogen and oxygen being consequently present in lower proportions. Taking the average of the Thames companies' supplies, it may be said that the proportion of oxygen dissolved in the Thames water amounts to 0·661 grains per gallon; that in the New River water amounts to 0·666 grains, while the East London water supply contains 0·645 grains, and the Kent Company's water 0·532 grains. The proportion of oxygen is, in the case of the Thames water, about eight times the amount required for the oxydation of the existing oxydizable matters (as indicated by the permanganate test); in the case of the New River water it amounts to about fourteen times; in that of the East London Company to about eleven times; and in that of the Kent Company to rather more than twenty times that required for the above purpose.

3. With respect to the ammonia existing in the water supplies, the proportion ranges from 0·001 to 0·002 grains per gallon, and is, in most instances, about the same as was found in the water during the winter of 1866-7.

4. The second table gives the proportions of the several saline constituents and of the volatile matter contained in an Imperial gallon of each of the companies' waters.

The observation which has been already made respecting the difference in the hardness of the several samples examined, in the winter and in the summer, applies also, generally, to the saline constituents, which are somewhat lower in amount at the present time than when we last examined the waters.

With reference to the second part of your letter, in which you request us to report on the system pursued by Dr. Frankland in obtaining and recording his analytical results, we have to offer the following few remarks.

Without discussing the question of the general applicability of Dr. Frankland's method of water analysis, which are at present we believe almost exclusively employed by him, we must express our dissent from one of the inferences which he founds upon his analytical results. In particular, we contend that the proportion of nitrogen discovered in water, in the forms of nitric acid, ammonia, &c., is not a trustworthy measure of the extent to which that water has, at some time or other, been contaminated by sewage, inasmuch as the nitrogen compounds existing in a water may, on the one hand, greatly exceed, and, on the other, equally fall short of those which would be furnished by the addition to the water of a given proportion of sewage (using the latter term in the broad sense in which it has been applied by Dr. Frankland); thus, for example, we cannot accept as a

correct representation of the relative condition of the East London water (from the river Lea), and that supplied by the Kent Company from deep wells in the chalk, the statement of Dr. Frankland in the Registrar General's Weekly Return for May last (No. 22, page 179) that the former contains 0 parts of previous sewage contamination (estimated) in 100,000 parts of water, while the latter exhibits 3,540 parts of previous sewage contamination in the same amount of water.

It scarcely need be pointed out by us, that the apparently higher results which Dr. Frankland's published analyses record, as to the solid constituents generally existing in water, when compared with those given in the reports of other analyses, are simply ascribable to the circumstance that they are calculated on 100,000 parts of water instead of on the Imperial gallon of 70,000 parts, as is the general custom.

In conclusion, we have to express our opinion that no useful results, but the reverse, can be attained by expressing in large multiples, as in tons (see Registrar General's weekly returns) the small proportions of mineral or other constituents, which analysis discovers in potable waters, and by designating as *impurities*, perfectly harmless substances which exist, in varying proportions, as normal constituents of nearly all natural waters.

We remain, &c.,

Hy. Letheby, M.B., M.A., &c.,
Professor of Chemistry in the London Hospital, and Medical Officer of Health for the City of London.

F. A. Abel, F.R.S., &c.
Chemist to the War and Ordnance Department, Woolwich.

W. Odling, M.B., F.R.S., &c.,
Professor of Chemistry in St. Bartholomew's Hospital.

London Hospital, July 13, 1868.

Table No. 1.—General Properties of the Water supplied by the Metropolitan Water Companies in May, June, and July 1868.

	THAMES COMPANIES.					New River.	East London.	Kent.
	West Middlesex.	Grand Junction.	Southwark and Vauxhall	Lambeth.	Chelsea.			
Where taken, and date (1868).	Cab-rank Portland Rd. June 15.	Cab-rank, Piccadilly, June 15.	Cab-rank, St. George's Church, July 4.	Cab-rank, Lambeth Baths, May 28.	Cab-rank, Whitehall, May 28.	Public tap, Aldgate, June 3.	Main to London Hospital, May 25.	Main at New Cross, June 3.
Hardness (degrees)	11·3	11·8	11·9	12·5	11·8	11·4	11·7	17·6
Ditto, after boiling	3·3	2·8	2·4	2·6	2·4	2·3	2·6	6·0
Dissolved gases per gallon (cub. in.)	13·13	12·73	13·33	12·80	12·60	11·27	11·33	13·33
Consisting of (per cent.) Carbonic acid	52·98	51·04	46·14	50·82	53·10	44·98	48·03	61·11
Oxygen	15·85	14·97	16·85	14·07	14·68	17·06	16·64	11·67
Nitrogen	31·17	33·99	37·01	35·11	32·22	37·96	35·33	27·22
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Oxygen required to oxidize—								
(*a*) Nitrate and protosalt iron	0·000	0·017	0·006	0·004	0·003	0·000	0·004	0·002
(*b*) Organic matter	0·070	0·071	0·091	0·079	0·072	0·047	0·052	0·022
Total per gallon (grains)	0·070	0·088	0·097	0·083	0·075	0·047	0·056	0·024
Oxygen dissolved in the water (grains)	0·712	0·652	0·768	0·616	0·633	0·666	0·645	0·532
Ammonia per gallon (grains)	0·001	0·002	0·001	0·002	0·002	0·001	0·001	0·001

Table No. 2.—Analyses of Water supplied by the Metropolitan Water Companies in May, June, and July 1868.

	THAMES COMPANIES.					New River.	East London.	Kent.
	West Middlesex.	Grand Junction.	Southwark and Vauxhall	Lambeth.	Chelsea.			
	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
Lime	6·041	7·455	6·804	7·504	7·371	6·944	6·818	10·479
Magnesia	0·329	0·532	0·784	0·350	0·343	0·336	0·504	0·791
Potassa	0·469	0·224	0·210	0·238	0·224	0·287	0·308	0·308
Soda	0·903	0·903	0·897	0·889	0·924	0·756	0·973	1·218
Ammonia	0·001	0·002	0·001	0·002	0·002	0·001	0·001	0·001
Oxide of Iron and Alumina	0·053	0·410	0·162	0·031	0·150	0·103	0·332	0·101
Carbonic Acid	4·527	5·954	5·002	5·644	5·641	5·519	5·268	6·702
Sulphuric Acid	1·060	0·892	0·690	1·162	0·963	0·560	1·175	3·462
Nitric Acid	0·203	0·229	0·209	0·420	0·424	0·339	0·153	1·220
Chlorine	0·955	0·953	1·071	2·931	1·604	1·785	1·440	2·780
Silica	0·441	0·420	0·375	0·525	0·378	0·224	0·434	1·127
Total	14·982	17·974	16·205	19·666	18·024	16·854	17·406	28·189
From which the oxygen equivalent of chlorine is to be deducted	0·212	0·212	0·238	0·651	0·356	0·397	0·320	0·618
Total solid matter per gallon	14·770	17·762	15·967	19·045	17·668	16·457	17·086	27·571
Organic and other volatile matter determined by incineration	0·480	0·500	0·501	0·165	0·420	0·320	0·490	0·280
Total solid matter obtained by analysis	15·200	18·262	16·468	19·210	18·088	16·777	17·576	27·85
Do. do. by evaporation	14·785	16·703	16·105	18·600	17·860	15·900	17·040	27·023

All the samples were bright when drawn from the Companies' Mains.

APPENDIX AJ.

Examples of the Registrar General's Monthly Reports on the London Waters.

Report for February 1867.

Royal College of Chemistry,
March 8th, 1867.

Sir,

I have the honour to submit to you in the following table the results of the chemical examination of the waters supplied to the metropolis during the month of February last.

Analysis of the Metropolitan Waters in February 1867. By Professor Frankland, F.R.S., of the Royal College of Chemistry.

Companies.	Date and Place of Collection.	Total Solid Impurity.	Organic Carbon.	Nitrogen, as Nitrates and Nitrites.	Ammonia.	Total Combined Nitrogen.	Previous Sewage Contamination (estimated).	Total Hardness.
Thames.								
Chelsea - -	1st February, Cab-rank, Horse Guards	28·58	·433	·337	·004	·371	2,420	16·2
West Middlesex -	1st February, Great Portland Street	28·68	·340	·356	·006	·412	2,630	16·2
Southwark and Vauxhall	1st February, Barclay's Brewery	29·08	·293	·357	·005	·361	2,630	16·8
Grand Junction -	1st February, Royal College of Chemistry	29·44	·417	·322	·004	·325	2,270	17·1
Lambeth - -	1st February, Cab-rank, Westminster Road	29·36	·423	·341	·005	·356	2,470	16·0
Other Sources.								
New River - -	15th February, Cab-rank, Tottenham Court Road	29·72	·272	·350	·003	·396	2,540	18·5
East London - -	16th February, Cab-rank, Shoreditch	33·56	·293	·357	·004	·392	2,620	18·8
Kent - - -	15th February, Waterworks, Deptford	39·84	·088	·421	·008	·428	3,300	23·1
South Essex* - -	16th February, Mr. Whiffin's, Romford	38·32	·143	·844	·007	·850	7,520	21·1
Column 1	2	3	4	5	6	7	8	9

* This company does not supply London.

The numbers in columns 3, 4, 5, 6, 7, 8, and 9 all relate to 100,000 parts of the waters. Column No. 3 shows the tota lsolid impurity contained in each water as delivered from the companies' mains. No. 4 shows the amount of carbon contained in the organic matter present in this solid impurity. No. 5, the amount of nitrogen in the form of salts of nitric and nitrous acids. Column No. 6 gives the amount of ammonia present in each sample, whilst column No. 7 records the total amount of nitrogen in the several forms of nitrogenous organic matter, salts of nitric and nitrous acids and ammonia. The most objectionable impurities contained in water supplied for domestic purposes are organic matters of animal origin, such as those contained in sewage and in the manure of cultivated land. After admixture with river or spring water these organic matters undergo slow oxidation, by which they are more or less completely resolved into comparatively innocuous inorganic compounds; their carbon is converted into carbonic acid and their hydrogen into water, and these products can no longer be identified in the aërated waters of the river or spring, but the nitrogen, which is an essential constituent of these noxious organic matters, is converted into nitrous and nitric acids, which, combining with the bases contained in most waters, remain dissolved, and constitute a record of the sewage or other analogous contamination to which the water has been subject. With certain corrections, the analytical determination of the nitrogen contained in these salts and in the form of ammonia writes, as it were, the history of the water as regards its contact with decomposing animal matter. Such *previous organic contamination* may be conveniently expressed in parts of average filtered London sewage, which if contained in 100,000 parts of the water, would produce the same results when thus completely oxidized. This previous sewage contamination or its equivalent is given in column 8, average filtered London sewage being taken as containing 10 parts of combined nitrogen in 100,000 parts, as deduced from the numerous analyses of Way, Hofmann, and Witt. Finally, column 9 expresses the amount of carbonate of lime, or its equivalent of other hardening salts, contained in 100,000 parts of the waters.

The table will now be intelligible; it may be thus read: 100,000 lbs. of East London water collected on 16th February at a cab rank in Shoreditch contained 33·56 lbs. of solid impurity; the organic matter, constituting a portion of this impurity, contained 0·293 lb. of carbon. This solid impurity also contained 0·357 lb. of nitrogen in the shape of nitrates and nitrites, besides 0·004 lb. of ammonia, whilst the total amount of *combined* nitrogen in every form was found to be 0·392 lb. Such combined nitrogen is to be carefully distinguished from the *uncombined* nitrogen of the air which is present in all natural waters. The above quantity of water supplied by the East London Company had been, after its descent to the earth as rain, contaminated with sewage or manure matter equivalent to 2,620 lbs. of average filtered London sewage. By gradual oxidation, partly in the pores of the soil, partly in the river Lea, and partly in the reservoirs, filters, and conduits of the East London Company, this sewage contamination had been entirely converted into comparatively innocuous inorganic compounds before its delivery to consumers. Finally, 100,000 parts of the East London water contained 18·8 lbs. of carbonate of lime, or their equivalent of other soap-destroying ingredients.

I have, &c.
E. Frankland.

The Registrar General,
&c. &c. &c.

Report for March 1867.

Royal College of Chemistry,
March 30th, 1867.

Sir,

I have the honour to submit to you in the following table the results of the chemical examination of the waters supplied to the metropolis during the present month. For the purpose of comparison I append also the results yielded by Loch Katrine water, as supplied to Glasgow, when submitted to the same analytical processes.

Analysis of the Metropolitan Waters in March 1867. By Professor Frankland, F.R.S., of the Royal College of Chemistry.

Companies.	Date and Place of Collection.	Total Solid Impurity.	Organic Carbon.	Nitrogen, as Nitrates and Nitrites.	Ammonia.	Total combined Nitrogen.	Previous Sewage Contamination (estimated).	Total Hardness.
Thames.								
Chelsea	4th March, Cab-rank, Horse Guards	30·96	·185	·352	·004	·355	2565	18·3
West Middlesex	4th March, Great Portland Street	30·26	·245	·313	·008	·319	2205	18·9
Southwark and Vauxhall	4th March, Barclay's Brewery	31·22	·256	·344	·005	·348	2495	19·1
Grand Junction	4th March, Royal College of Chemistry	31·54	·311	·345	·004	·348	2495	19·4
Lambeth	4th March, Cab-rank, Westminster Road	32·10	·289	·341	·008	·347	2485	18·5
Other Sources.								
New River	16th March, Cab-rank, Tottenham Court Road	27·70	·284	·332	·004	·335	2365	16·8
East London	15th March, Old Ford Waterworks	30·36	·270	·320	·004	·323	2245	18·3
Kent	15th March, New Cross Inn, New Cross	39·90	·114	·417	·004	·420	3215	23·0
Loch Katrine	February, Glasgow	3·28	·256	·031	·002	·041	0	·3
Column 1	2	3	4	5	6	7	8	9

The numbers in columns 3, 4, 5, 6, 7, 8, and 9 all relate to 100,000 parts of the waters. The table is to be read thus: 100,000 lbs. of the Chelsea Company's water collected on 4th March at the Horse Guards' cab rank contained 30·96 lbs. of solid impurity; the organic matter, constituting a portion of this impurity, contained 0·185 lb. of carbon. This solid impurity also contained 0·352 lb. of nitrogen in the form of nitrates and nitrites, besides 0·004 lb. of ammonia, whilst the total amount of *combined* nitrogen in every form was 0·355 lb. The above quantity of water supplied by the Chelsea Company had been, after its descent to the earth as rain, contaminated with sewage or manure matter equivalent to 2,565 lbs. of average filtered London sewage. By gradual oxidation, partly in the pores of the soil, partly in the Thames or its tributaries, and partly in the reservoirs, filters, and conduits of the Chelsea Company, this sewage contamination had been entirely converted into comparatively innocuous inorganic compounds before its delivery to consumers. Finally, 100,000 lbs. of the Chelsea Company's water contained 18·3 lbs. of carbonate of lime, or their equivalent of other soap-destroying ingredients.

The water supplied by the Grand Junction Company has been specially examined for *present sewage contamination* (i.e. sewage existing as such at the time the analysis was made), but it was found to be perfectly free from any such contamination.

All the waters were clear, with the exception of that delivered by the Southwark and Vauxhall Company, which was turbid when drawn from the main.

I have, &c.

The Registrar General, &c. &c. &c.

E. Frankland.

Report for August 1867.

Royal College of Chemistry,
August 27th, 1867.

Sir,

I have the honour to submit to you in the following table the results of the chemical examination of the waters supplied to the metropolis during the month of August. For the purpose of comparison I append also the results yielded by Loch Katrine water, as supplied to Glasgow, when submitted to the same analytical processes.

The numbers in columns 3, 4, 5, 6, 7, 8, and 9 all relate to 100,000 parts of the waters. The table is to be read thus: 100,000 lbs. of Chelsea water collected 1st August at the Horse Guards' cab rank contained 25·65 lbs. of solid impurity; the organic matter, constituting a portion of this impurity, contained ·274 lb. of carbon. This solid impurity also contained ·217 lb. of nitrogen in the form of nitrates and nitrites, besides ·002 lb. of ammonia, whilst the total amount of *combined* nitrogen in every form was ·226 lb. The above quantity of water supplied by the Chelsea Company had been, after its descent to the earth as rain, contaminated with sewage or manure matter equivalent to 1,275 lbs. of average filtered London sewage. By gradual oxidation, partly in the pores of the soil, partly in the reservoirs, filters, and conduits of the company, this sewage contamination had been converted into comparatively innocuous inorganic compounds before its delivery to consumers. Finally, 100,000 lbs. of the Chelsea Company's water contained 18·14 lbs. of carbonate of lime, or an equivalent quantity of other soap-destroying ingredients.

ANALYSIS of the METROPOLITAN WATERS in AUGUST 1867. By Professor FRANKLAND, F.R.S., of the Royal College of Chemistry.

Companies.	Date and Place of Collection.	Total solid Impurity in 100,000 parts.	Organic Carbon.	Nitrogen, as Nitrates and Nitrites.	Ammonia.	Total combined Nitrogen.	Previous Sewage Contamination (estimated).	Total Hardness.
THAMES.								
Chelsea - - -	1st August, Cab-rank, Horse Guards	25·65	·274	·217	·002	·226	1,275	18·14
West Middlesex -	1st August, Cab-rank, Portland Road	28·60	·239	·166	·001	·173	745	18·71
Southwark and Vauxhall	1st August, Barclay's Brewery	25·30	·228	·145	·001	·155	565	18·42
Grand Junction -	2nd August, Cab-rank, Woodstock Street	25·24	·230	·136	·001	·142	435	18·00
Lambeth - - -	1st August, Cab-rank, Westminster Road	26·24	·312	·199	·002	·209	1,105	18·28
OTHER SOURCES.								
New River - -	1st August, Cab-rank, Tottenham Court Road	23·50	·124	·160	·001	·165	665	17·28
East London - -	1st August, Palmer's Lamp Black Works, Old Ford	23·30	·133	·054	·001	·059	0	18·42
Kent - - -	2nd August, Deptford Railway Station	40·30	·088	·339	·002	·348	2,495	27·05
Loch Katrine - -	February, Glasgow	3·28	·256	·031	·002	·041	0	0·3
Column 1	2	3	4	5	6	7	8	9

All the waters were clear and transparent when drawn from the companies' mains, except those delivered by the Southwark and Kent Companies. The constant turbidity of the Southwark Company's water indicates some grave defect in their process of filtration. The Kent Company's water had a slightly milky appearance and was filled with light brown floating particles.

I have, &c.
E. FRANKLAND.

The Registrar General,
&c. &c. &c.

The Registrar General, in the body of his Report, remarks on this as follows :—

By Dr. Frankland's analysis of the water supplied by the London companies, it appears that both the New River and the East London waters contained in 100,000 tons 23 tons of extraneous matter, the other companies still more, while the West Middlesex water contained 29 tons and the Kent 40 tons of stuff of various kinds. The previous sewage contamination of all the waters at the time of analysis had apparently been converted into innocuous compounds. By this test the East London waters were then the best, the Chelsea and the Kent waters the worst of the eight. The turbidity of the Southwark water implies some defect in the process of filtration.

The following is the general Report for the whole year 1867 :—

REPORT on the ANALYSIS of the WATERS supplied by the METROPOLITAN WATER COMPANIES during the several Months of the Year 1867, by Professor FRANKLAND, F.R.S., &c.

Royal College of Chemistry.
February 4th, 1868.

SIR,

I HAVE the honour to lay before you a summary of the results of my monthly analytical examinations of the waters supplied to the metropolis during the year 1867. During the past year 105 different samples of water have been submitted to chemical analysis. By new analytical processes devised at the commencement of the year, I have been able in eleven out of the twelve months to obtain determinations of the carbon contained in the organic matters present in the waters, and also to estimate the amount of contamination suffered by each sample from the admixture of sewage or manure matter. In connexion with the opinions now generally entertained with regard to the propagation of certain forms of disease, such as cholera and typhoid fever, by means of spores or germs contained in excrementitious matters, the search for sewage pollution in the metropolitan waters assumes a high degree of importance. The nitrogenous organic matters contained in sewage or manure undergo slow oxidation and conversion into mineral compounds when mixed with water, their carbon is converted into carbonic acid and their hydrogen into water. These products can no longer be identified in the aërated waters of a river, spring, or lake; but the nitrogen of these organic matters is transformed successively into ammonia, nitrous acid, and nitric acid. The two latter combine with bases, and, together with the ammonia, constitute a record of the sewage or other analogous contamination to which the water has been subject. With certain corrections presently to be mentioned, the analytical determination of the nitrogen contained in these mineral compounds furnishes the previous history of the water as regards its contact with decomposing nitrogenous organic matter. In my monthly reports to you during the past year, this determination has been employed for the estimation of the previous sewage contamination of each water, expressed in parts of average filtered London sewage, which, if thus completely oxidized in a river, would yield a like amount of nitrogen in the forms of ammonia, nitrates, and nitrites. For this purpose average filtered London sewage may be taken as containing 10 parts of combined nitrogen in 100,000 parts, as deduced from the numerous analyses of Hofmann and Witt and of Way and Odling. The number so obtained as the previous sewage contamination of a water requires, however, a correction, since rain water itself contains combined nitrogen as ammonia, nitrite of ammonia, and nitrate of ammonia. The amount of these substances present in the rain which falls at Rothampstead has been determined by a series of monthly analyses made independently, on the one hand by Messrs. Lawes and Gilbert, and on the other by Professor

Way, and extending over two years. The results of these chemists give, as the average amount of nitrogen in the forms of ammonia, nitrite of ammonia, and nitrate of ammonia, 0·0985 part in 100,000 parts of rain water. This corresponds to 985 parts of previous sewage contamination, which number was deducted from the previous sewage contamination of the metropolitan waters, as determined by analysis in the months of February to October inclusive. But the experience gained in the examination of numerous samples of water from Wales and Cumberland during the past summer and autumn teaches that this deduction is far too large. The maximum amount of ammonia contained in forty-two such samples of water was only 0·008 part in 100,000, whilst the average amount of nitrogen in the form of nitrous and nitric acid observed by Messrs. Lawes, Gilbert, and Way, and this in thunder-rain only, was but ·024 part in 100,000. It may, therefore, be safely asserted, that the maximum amount of combined nitrogen derived by natural waters from aërial sources does not exceed ·024 + ·008 = ·032 part in 100,000, which gives the number 320 to be deducted from the previous sewage contamination as determined by analysis. In the following tables this number, therefore, has been used throughout in lieu of the number 985, which was employed in my monthly reports from February to October inclusive.

Table A. gives the amount of solid impurity left on evaporation by 100,000 parts by weight of each sample of water.

Table B. the amount of carbon contained in the organic matter constituting a portion of this solid impurity (organic carbon).

Table C. the amount of nitrogen in the form of nitrates and nitrites.

Table D. the amount of ammonia.

Table E. the total quantity of combined nitrogen.

Table F. the amount of previous sewage contamination estimated as above described from Tables D. and E.

Table G. expresses the hardness of each sample of water, that is, the number of parts of carbonate of lime, (or its equivalent of other soap-destroying salts,) contained in 100,000 parts of the water, whilst Table H. exhibits a comparison of the potable waters used in London with those supplied to Romford (by the South Essex Company, whose mains have not yet reached London) and to some other towns.

On referring to Table A. we find that in December 1867, 100,000 lbs. of the water delivered by the Chelsea Company contained 29·8 lbs. of solid impurity. Table B. informs us that the organic matter constituting a portion of this impurity contained ·202 lbs. of carbon; Table C. that ·243 lb. of nitrogen existed in this quantity of the Chelsea water in the form of nitrates and nitrites; Table D. that 100,000 lbs. of this water contain ·002 lb. of ammonia; whilst Table E. shows that it contained a total of ·252 lb. of combined nitrogen in the different forms of organic matter, nitrates, nitrites, and ammonia. Table F. states that 100,000 lbs. of the water had been, after descending as rain, contaminated with sewage or manure matter equivalent to 2,130 lbs. of average filtered London sewage; and Table G. informs us that every 100,000 lbs. of this water contained 21·7 lbs. of carbonate of lime or its equivalent of other hardening salts.

For the purposes of comparison I have also submitted to analysis during the past year the water supplied to the towns of Glasgow, Manchester, Lancaster, and Leicester, and to the metropolitan suburb of Romford. The results of these analyses are compared in Table H. with the mean results of the analysis of the metropolitan waters during the year. The last column of this table also shows the number of lbs. of good hard soap which would be destroyed by 100,000 lbs. of each water used for washing, before any useful detergent effect would be produced.

When compared with the tables given in my last annual report the following analytical results show that the water delivered by the Chelsea, West Middlesex, Southwark, East London, and Kent companies was softer than in 1866, the New River Company's water had exactly the same mean hardness in both years, whilst that delivered by the Grand Junction and Lambeth companies was slightly harder in 1867 than in 1866

The total solid impurity exhibits an increase over 1866 in every case except that of the East London Company, in which a marked decrease has occurred. In former years the quality of this latter company's water was inferior to that of the remaining metropolitan supply, but it has been so much improved during the past year that this water is now only inferior to the supply distributed by the New River Company.

Considering the great previous sewage contamination exhibited by the river waters supplied to London, it is much to be regretted that these waters are not more effectively filtered before distribution. Only on one occasion during the whole year have I obtained a transparent sample of water from the Southwark Company's mains. The Grand Junction and Kent Company's waters were turbid four times out of twelve, the Chelsea thrice, and the West Middlesex, Lambeth, and East London each twice out of the twelve occasions when the samples were drawn for analysis. The New River Company stands alone in the perfection of its filtering apparatus; on no occasion during the past year has this company's water exhibited the slightest turbidity, thus proving that perfect filtration is compatible with the largest daily supply furnished by any one company in London. The seven companies, who occasionally or habitually send out turbid water, subject the inhabitants of more than 300,000 houses to the unnecessary expense of private filtration.

The distribution of water in the metropolis still continues, with but slight exceptions, upon the intermittent system, which has been abolished in almost every other town of importance in the United Kingdom. In addition to the well-known evils attending the storage of water in butts and cisterns under this system, there is the danger of the leakage of sewage into the pipes whilst the pressure is withdrawn. An instructive instance of this occurred in the West Middlesex Company's district in June last. The water drawn from this company's main on the 1st June was found on analysis to contain rather more than one per cent. of fresh sewage. In answer to my inquiries the company's engineer informed me that a leakage had occurred in one of the mains near a gullyhole. This fracture, which was repaired on the 3d of June soon after its discovery, occurred to a main from which the water pressure was removed at night, and there can be little doubt that during the absence of the internal pressure sewage gained access to the interior of the main. It is only right to add that, with the exception of this accidental contamination, and one other instance of slight turbidity, the water distributed by the West Middlesex Company has been of as great a degree of purity as it is possible to attain in water derived from the Thames at Teddington.

I have, &c.
E. FRANKLAND.

The Registrar General,
&c. &c. &c.

TABLE A.

WEIGHT of SOLID IMPURITY in 100,000 parts of the WATERS.

Names of Companies.	1867.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea -	31·34	28·58	30·96	27·86	29·34	28·28	26·54	25·65	25·90	26·28	29·6	29·8	29·17
West Middlesex -	31·99	28·68	30·26	28·06	27·16	27·22	26·20	28·60	24·60	23·70	28·4	29·6	27·87
Southwark -	32·42	29·08	31·22	28·52	28·82	29·70	20·02	25·30	25·54	25·90	29·8	29·6	28·49
Grand Junction -	32·82	29·44	31·54	28·20	29·84	28·42	24·86	25·24	25·60	25·10	29·8	29·0	28·32
Lambeth -	31·88	29·36	32·10	28·68	29·64	28·18	26·24	26·24	26·44	26·90	31·0	29·8	28·88
OTHER SOURCES.													
New River -	31·39	29·72	27·70	26·44	24·68	23·12	24·22	23·50	23·90	26·60	25·2	29·8	26·44
East London -	35·68	33·56	30·36	27·82	26·86	27·22	24·68	23·30	24·74	27·22	30·2	31·0	28·55
Kent - -	39·40	39·84	39·90	40·12	39·22	39·04	38·52	40·30	39·90	41·74	42·0	31·8	39·31

Table B.

Organic Carbon in 100,000 parts of the Waters.

Names of Companies.	1867.											
	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.												
Chelsea - -	·433	·185	·267	·287	·261	·212	·274	·193	·304	·263	·202	·262
West Middlesex -	·340	·245	·224	·231	1·020	·232	·239	·173	·258	·286	·174	·311
Southwark -	·293	·256	·166	·260	·231	·237	·228	·197	·261	·259	·217	·237
Grand Junction -	·417	·311	·218	·278	·265	·189	·230	·170	·224	·277	·396	·270
Lambeth -	·423	·289	·164	·465	·325	·241	·312	·237	·218	·268	·216	·287
Other Sources.												
New River -	·272	·284	·273	·163	·217	·145	·124	·115	·129	·104	·104	·175
East London -	·293	·270	·382	·245	·237	·206	·133	·183	·164	·118	·141	·216
Kent - -	·088	·114	·131	·254	·165	·133	·088	·099	·120	·113	·142	·131

Table C.

Nitrogen as Nitrates and Nitrites in 100,000 parts of the Waters.

Names of Companies.	1867.											
	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.												
Chelsea - -	·337	·352	·267	·199	·214	·204	·217	·188	·202	·222	·243	·240
West Middlesex -	·356	·313	·269	·220	·218	·182	·166	·151	·136	·225	·266	·227
Southwark -	·357	·344	·298	·207	·170	·221	·145	·144	·167	·183	·228	·224
Grand Junction -	·322	·345	·248	·210	·204	·319	·136	·162	·141	·210	·269	·233
Lambeth -	·341	·341	·290	·184	·220	·276	·199	·157	·207	·229	·239	·244
Other Sources.												
New River -	·350	·332	·274	·205	·198	·199	·160	·322	·219	·187	·298	·249
East London -	·357	·320	·264	·161	·150	·125	·054	·194	·108	·156	·208	·191
Kent - -	·421	·417	·409	·363	·320	·374	·339	·450	·345	·364	·413	·383

Table D.

Ammonia in 100,000 parts of the Waters.

Names of Companies.	1867.											
	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.												
Chelsea - -	·004	·004	·002	·004	·004	·006	·002	·001	·001	·003	·002	·003
West Middlesex -	·006	·008	·004	·004	·120	·006	·001	·001	·001	·002	·000	·014
Southwark -	·005	·005	·002	·006	·002	·008	·001	·001	·002	·001	·001	·003
Grand Junction -	·004	·004	·004	·005	·004	·006	·001	·002	·001	·001	·001	·003
Lambeth - -	·005	·008	·004	·006	·001	·006	·002	·001	·002	·001	·000	·003
Other Sources.												
New River -	·003	·004	·002	·004	·001	·006	·001	·002	·001	·001	·000	·002
East London -	·004	·004	·010	·002	·002	·006	·001	·001	·001	·001	·000	·003
Kent - -	·008	·004	·002	·002	·001	·002	·002	·003	·000	·001	·123	·013

Table E.

Total combined Nitrogen in 100,000 parts of the Waters.

Names of Companies.	1867.											
	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec	Mean.
Thames.												
Chelsea - -	·371	·355	·318	·231	·217	·209	·226	·194	·212	·242	·252	·257
West Middlesex -	·412	·319	·323	·274	·421	·187	·173	·159	·140	·245	·291	·268
Southwark -	·361	·348	·293	·278	·172	·228	·155	·152	·210	·203	·239	·240
Grand Junction -	·325	·348	·310	·228	·207	·324	·142	·169	·145	·229	·289	·247
Lambeth - -	·356	·347	·362	·227	·229	·281	·209	·166	·230	·249	·273	·266
Other Sources.												
New River -	·396	·335	·328	·285	·199	·204	·165	·327	·224	·208	·301	·270
East London -	·392	·323	·314	·190	·152	·130	·059	·202	·118	·164	·212	·205
Kent - -	·428	·420	·414	·384	·321	·376	·348	·454	·348	·369	·516	·398

Table F.

Previous Sewage Contamination in 100,000 parts of the Waters.

Names of Companies.	1867.											
	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.												
Chelsea	3,080	3,230	2,360	1,700	1,850	1,770	1,860	1,570	1,710	1,920	2,130	2,107
West Middlesex	3,290	2,870	2,400	1,910	2,850	1,550	1,350	1,200	1,050	1,950	2,340	2,069
Southwark	3,290	3,160	2,670	1,800	1,390	1,950	1,140	1,130	1,360	1,520	1,970	1,953
Grand Junction	2,930	3,160	2,190	1,820	1,750	2,920	1,050	1,310	1,100	1,790	2,380	2,036
Lambeth	3,130	3,150	2,610	1,570	1,890	2,490	1,680	1,260	1,760	1,980	2,070	2,144
Other Sources.												
New River	3,200	3,030	2,430	1,760	1,670	1,720	1,290	2,910	1,880	1,560	2,660	2,192
East London	3,280	2,910	2,400	1,300	1,190	980	230	1,630	770	1,250	1,760	1,610
Kent	3,950	3,880	3,780	3,320	2,890	3,430	3,080	4,200	3,130	3,330	4,820	3,619

Table G.

Degrees of Hardness (1 deg. = 1 part of carbonate of lime, or its equivalent,) in 100,000 parts of the Waters.

Names of Companies.	1867.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.													
Chelsea	18·5	16·2	18·3	17·7	22·0	20·3	19·7	18·1	18·7	17·5	20·5	21·7	19·10
West Middlesex	18·8	16·2	18·9	16·3	20·8	19·4	19·4	18·7	17·8	16·0	20·6	22·8	18·80
Southwark	18·8	16·8	19·1	17·7	20·8	20·9	19·7	18·4	18·8	16·0	21·7	21·7	19·20
Grand Junction	19·4	17·1	19·4	17·7	21·4	20·9	19·1	18·0	19·4	17·5	22·8	20·8	19·62
Lambeth	19·4	16·0	18·5	17·7	21·4	20·9	20·3	18·3	19·1	18·9	22·8	22·8	19·67
Other Sources.													
New River	19·4	18·5	16·8	16·3	18·8	16·3	19·1	17·3	18·8	18·7	18·5	22·8	18·44
East London	20·5	18·8	18·3	16·0	20·0	19·7	18·3	18·4	17·4	20·5	21·8	23·1	19·40
Kent	22·5	23·1	23·0	21·1	28·0	28·3	28·8	27·0	26·1	25·8	29·1	24·6	25·61

Table H.

Comparison of the London with some Non-Metropolitan Waters.

The Numbers in this Table relate to 100,000 parts of each Water.

Name of Water.	Total Solid Impurity.	Organic Carbon.	Nitrogen as Nitrates and Nitrites.	Ammonia.	Total combined Nitrogen.	Previous Sewage Contamination.	Hardness.	Soap destroyed.
Thames.								
Chelsea	29·17	·262	·240	·003	·257	2,107	19·10	229·2
West Middlesex	27·87	·311	·227	·014	·268	2,069	18·80	225·6
Southwark	28·49	·237	·224	·003	·240	1,953	19·20	230·4
Grand Junction	28·32	·270	·233	·003	·247	2,036	19·62	235·4
Lambeth	28·88	·287	·244	·003	·266	2,144	19·67	236·0
Other Sources.								
New River	26·44	·175	·249	·002	·270	2,192	18·44	221·3
East London	28·55	·216	·191	·003	·205	1,610	19·40	232·8
Kent	39·31	·131	·383	·013	·398	3,619	25·61	307·3
Non-Metropolitan.								
South Essex, from chalk wells at Grays	37·98	·164	·848	·006	·852	8,205	21·6	258·8
Glasgow, from Loch Katrine	3·28	·256	·031	·002	·041	0	0·3	3·6
Lancaster, from Bleasdale Fells	3·54	·157	·036	·001	·038	50	0·1	1·2
Manchester, from Derbyshire hills	6·80	·242	·001	·001	·028	0	2·7	32·4
Leicester, waterworks supply	23·70	·506	·001	·001	·022	0	13·4	160·8

AVERAGE NUMBER of HOUSES, &c., supplied by the several LONDON WATER COMPANIES during the Year 1867; the AVERAGE DAILY SUPPLY of WATER in Gallons, in Cubic Metres* for all purposes, and in Cubic Metres for Domestic purposes; also the Number of Litres† supplied daily to each House. (Compiled from Returns furnished by the several Water Companies during the Year.)

Water Companies.	Average Number of Houses supplied during the Year.	Average Daily Supply of Water during the Year in			Litres for Domestic purposes daily to each House.
		Gallons.‡	Cubic Metres.‡	Cubic Metres for Domestic purposes (estimated).	
Total	441,442	98,600,248	447,985	370,542	839
From Thames	200,824	49,042,467	222,822	190,343	948
From Lea and from other Sources	240,618	49,557,781	225,163	180,199	749
FROM THAMES.					
Chelsea	26,875	8,087,258	36,744	31,265	1,163
West Middlesex	36,881	8,816,486	40,057	37,344	1,013
Southwark and Vauxhall	71,558	13,629,758	61,926	53,999	755
Grand Junction	27,190	9,533,432	43,315	32,655	1,201
Lambeth	38,320	8,975,533	40,780	35,080	915
FROM LEA AND OTHER SOURCES.					
New River	113,462	23,790,667	108,091	87,501	771
East London	92,652	19,298,241	87,681	65,056	702
Kent	34,504	6,468,873	29,391	27,642	801
Columns	1	2	3	4	5

Note.—According to returns of the London Water Companies made to the Select Committee on East London Water Bills (Session 1867), it is estimated that on an average, during the year 1866, about 80 per cent. of the total average daily supply of water for all purposes was for domestic use; the proportions supplied for the year 1866 have been applied in estimating the quantities for the year 1867 in column 4, showing the cubic metres probably used for domestic purposes.

The average daily quantity of water supplied by the London Companies during the year 1867 was 98,600,248 gallons (447,985 cubic metres, equal to about as many *tuns* by measure, *tons* by weight), of which about 81,555,056 gallons (370,542 cubic metres) were probably used for domestic purposes. The quantity used for house supply daily was 839 litres to each house, and 120 litres (=26·5 gallons) to each person.

* A cubic metre is equal in volume to 35·3174 cubic feet, or to 220·0967 imperial gallons. It is nearly equivalent to the old English *tun* of four hogsheads, holding 35·248 cubic feet. It is in general use on the Continent; and its volume of water weighs a metric ton, differing inconsiderably in weight from the ton in common use.

† 4·543458 litres equal one gallon.

‡ The quantities of water in columns 2 and 3 include the supply for manufactures and for various purposes other than for domestic consumption.

REPORT for January 1868.

Royal College of Chemistry,
January 31st, 1868.

SIR,

I HAVE the honour to submit to you in the following Table the results of the chemical examination of the waters supplied to the metropolis during the month of January. For the purpose of comparison I append also the results yielded by Loch Katrine water, as supplied to Glasgow, and by waters supplied to the towns of Lancaster, Manchester, Leicester, and Preston, when submitted to the same analytical processes.

The numbers in columns 4, 5, 6, 7, 8, 9, 10, and 11 all relate to 100,000 parts of the waters. The table is to be read thus: the Chelsea Company's water collected on 21st January at the Horse Guards' cab rank had a temperature of 7·2 C., it contained 29·2 lbs. of solid impurity; the organic matter, constituting a portion of this impurity, contained ·353 lb. of carbon and ·058 lb. nitrogen. This solid impurity also contained ·339 lb. of nitrogen in the form of nitrates and nitrites, besides ·001 lb. of ammonia, whilst the total amount of *combined* nitrogen in every form was ·339 lb. The above quantity of water supplied by the Chelsea Company had been, after its descent to the earth as rain, contaminated with sewage or manure matter equivalent to 3,080 lbs. of average filtered London sewage. By gradual oxidation, partly in the pores of the soil, partly in the Thames and its tributaries, and partly in the reservoirs, filters, and conduits of the company, this sewage contamination had been converted into comparatively innocuous inorganic compounds before its delivery to consumers. Finally, 100,000 lbs. of the Chelsea Company's water contained 15·4 lbs. of carbonate of lime, or an equivalent quantity of other soap-destroying ingredients.

The waters delivered in London during the latter part of January by the Chelsea, and especially by the Southwark and Lambeth companies, were in such a muddy condition as to render them totally unfit for domestic use. The Thames has overflowed its banks above the point at which the water supply is withdrawn, and by washing the surfaces of cultivated fields and mingling with the contents of stagnant ditches and ponds has become contaminated to an intolerable degree. Those companies which, like the West Middlesex and Grand Junction, possess ample and efficient filtering apparatus, were enabled so far to cope with the difficulty as to send out their supply free from suspended matters. A week later, however, than the date when the samples were collected, the water of the Grand Junction Company had also become turbid, but much less so than that delivered by the Southwark and Lambeth companies. It will be seen from a reference to the analytical tables that the Thames was contaminated at the time the samples were taken with double the usual proportion of organic matter. Besides dissolving the soluble manure matters from cultivated fields, the recent heavy rains flushed the sewers of Oxford, Windsor, &c., dislodging great quantities of putrescent animal matters and sweeping them into the Thames: hence the large proportion of organic carbon and nitrogen, and the great previous sewage contamination in the waters of those companies which derive their supply from that river. The West Middlesex Company's water, though well filtered and perfectly transparent, had been thus contaminated to an extent which would be produced by the admixture of one-third of a gallon of average filtered London sewage with each ten gallons of the water. The River Lea also exhibits a very high previous sewage contamination, but at the time when the New River and East London companies' samples were collected it had not been affected like the Thames, for, although the East London water was full of suspended brown particles, the analyses of these waters show that the organic carbon and nitrogen are remarkably low for the season. The Kent Company's water was slightly turbid from yellow particles.

I have, &c.
E. FRANKLAND.

The Registrar General,
&c. &c. &c.

ANALYSIS of the METROPOLITAN WATERS in JANUARY 1868. By Professor FRANKLAND, F.R.S. of the Royal College of Chemistry.

Companies.	Date and Place of Collection.	Temperature* in centigrade degrees.	Total Solid Impurity in 100,000 gallons.	Organic Carbon.	Organic Nitrogen.	Nitrogen, as Nitrates and Nitrites.	Ammonia.	Total combined Nitrogen.	Previous Sewage Contamination. (Estimated.)	Total Hardness
THAMES.										
Chelsea	21st January, Cab Rank, Horse Guards	7·2 C.	29·2	·353	·058	·339	·001	·339	3080	15·4
West Middlesex	21st January, Cab Rank, Portland Road	8·0 „	31·4	·271	·027	·367	·001	·395	3360	17·3
Southwark and Vauxhall	21st January, Barclay's Brewery	7·7 „	32·2	·485	·061	·323	·001	·385	2920	17·5
Grand Junction	20th January, Cab Rank, Woodstock Street	6·6 „	37·5	·345	·031	·366	·000	·397	3340	19·7
Lambeth	21st January, Cab Rank, Lambeth Road	7·2 „	30·4	·542	·062	·336	·002	·400	3050	16·5
OTHER SOURCES.										
New River	21st January, Cab Rank, Tottenham-court-road	8·0 „	30·2	·115	·014	·361	·001	·376	3300	20·5
East London	22d January, Slater's Lamp Black Works, Old Ford Road	6·4 „	36·0	·147	·024	·307	·001	·332	2760	22·8
Kent	23d January, Deptford Railway Station	7·2 „	44·8	·064	·013	·408	·001	·422	3770	26·2
Loch Katrine	February, Glasgow	—	3·28	·256	·008	·031	·002	·041	0	0·3
Lancaster	September, Lancaster	—	3·54	·157	·001	·036	·001	·038	50	0·1
Manchester	November, Manchester	—	6·8	·242	·026	·001	·001	·021	0	2·7
Leicester	November, Leicester	—	23·7	·506	·020	·001	·001	·022	0	13·4
Preston	December, Preston	—	14·7	·515	·040	·001	·003	·044	0	6·7
Column 1	2	3	4	5	6	7	8	9	0	11

* The average mean temperature of the Thames during the three days, January 20, 21, and 22, was 5·7° Centigrade; the average during the week ending January 18th was 3·3° Centigrade.

REPORT for February 1868.

Royal College of Chemistry,
SIR, February 29th, 1868.

I HAVE the honour to submit to you in the following table the results of the chemical examination of the waters supplied to the metropolis during the month of February. For the purpose of comparison I append also the results yielded by Loch Katrine water, as supplied to Glasgow, and by the waters supplied to the towns of Lancaster, Manchester, Leicester, Preston, and Worthing, when submitted to the same analytical processes.

The waters delivered by the New River, East London, and Kent companies were clear and transparent, but, with the exception of the West Middlesex, all the companies drawing their supply from the Thames were delivering imperfectly filtered water on the day when the samples were taken. The Lambeth Company's water was so muddy that brightly illuminated objects could not be seen through a stratum of it 12 inches deep. The Chelsea Company's water was but little better in this respect, and the supply of both companies was, on this ground alone, entirely unfit for domestic use. The water delivered by the Southwark and Grand Junction companies was only slightly turbid.

The organic matter contained in all the samples of water, except those of the West Middlesex and Southwark companies, was highly nitrogenized, and therefore probably of animal origin to a considerable extent.

The condition of the Kent Company's water delivered at the Deptford Railway Station on the 7th inst. presented remarkable peculiarities. It contained the very large amount of 59·2 parts of solid impurity in 100,000 parts of the water, 42 parts being the maximum and 39·3 the mean amount observed in this company's water during the year 1867. Of the above 59·2 parts no less than 14·7 were common salt, the occurrence of which in such quantity is difficult to account for, except on the supposition that the company's wells have some connexion either with the sea or the brackish reaches of the Thames. The previous sewage contamination was also higher than that observed on any former occasion.

For the first time since February 1867 the East London Company's water exceeds that of the New River Company in previous sewage contamination.

I have, &c.
E. FRANKLAND.

The Registrar General,
&c. &c. &c.

ANALYSIS of the METROPOLITAN WATERS in FEBRUARY 1868. By Professor FRANKLAND, F.R.S., of the Royal College of Chemistry,

Companies.	Date and Place of Collection.	Temperature in Centigrade degrees.	Total Solid Impurity in 100,000 parts.	Organic Carbon.	Organic Nitrogen.	Nitrogen, as Nitrates and Nitrites.	Ammonia.	Total combined Nitrogen.	Previous Sewage Contamination. (estimated.)	Total Hardness.
THAMES.										
Chelsea	4th February, Cab rank, Horse Guards	7·2 C.	30·8	·326	·052	·340	·002	·394*	3,100	18·8
West Middlesex	4th February, Cab rank, Portland Road	7·2 „	30·0	·357	·031	·321	·002	·354	2,910	18·4
Southwark and Vauxhall	4th February, Barclay's Brewery	7·7 „	32·2	·324	·032	·344	·001	·377	3,130	19·7
Grand Junction	4th February, Cab rank, Woodstock Street	5·8 „	32·6	·329	·055	·343	·001	·399	3,120	21·1
Lambeth	4th February, Cab Rank, Lambeth Road	7·2 „	31·2	·360	·045	·310	·001	·356	2,790	18·5
OTHER SOURCES.										
New River	4th February, Cab rank, Tottenham Court Road	6·6 „	30·8	·217	·026	·355	·001	·382	3,240	20·5
East London	5th February, Slater's Lamp Black Works, Old Ford Road	7·2 „	34·4	·272	·037	·370	·003	·410	3,400	20·5
Kent	7th February, Deptford Railway Station	11·6 „	59·2	·081	·013	·564	·001	·578	5,330	30·0
Loch Katrine	February 1867, Glasgow	—	3·28	·256	·008	·031	·002	·041	0	0·3
Lancaster	September, Lancaster	—	3,54	·157	·001	·036	·001	·038	50	0·1
Manchester	November, Manchester	—	6·8	·242	·026	·001	·001	·028	0	2·7
Leicester	November, Leicester	—	23·7	·506	·020	·001	·001	·022	0	13·4
Preston	December, Preston	—	14·7	·515	·040	·001	·003	·044	0	6·7
Worthing	November, Worthing	—	36·7	·162	·000	·426	·000	·426	3,940	23·8
Column 1	2	3	4	5	6	7	8	9	10	11

* In the last month's report through a clerical error the total combined nitrogen in the Chelsea Company's water was given as ·339 instead of ·398.

The numbers in columns 4, 5, 6, 7, 8, 9, 10, and 11 all relate to 100,000 parts of the waters. The table is to be read thus: the Chelsea Company's water collected on 4th February at the Horse Guards' cab rank had a temperature of 7·2° C.; 100,000 lbs. of it contained 30·8 lbs. of solid impurity; the organic matter, constituting a portion of this impurity, contained ·326 lb. of carbon and ·052 lb. of nitrogen. This solid impurity also contained ·340 lb. of nitrogen in the form of nitrates and nitrites, besides ·002 lb. of ammonia, whilst the total amount of *combined* nitrogen in every form was ·394 lb. The above quantity of water supplied by the Chelsea Company had been, after its descent to the earth as rain, contaminated with sewage or manure matter equivalent to 3,100 lbs. of average filtered London sewage. By gradual oxidation, partly in the pores of the soil, partly in the Thames and its tributaries, and partly in the reservoirs, filters, and conduits of the company, this sewage contamination had been converted into innocuous inorganic compounds before its delivery to consumers. Finally, 100,000 lbs. of the Chelsea Company's water contained 18·8 lbs. of carbonate of lime, or an equivalent quantity of other soap-destroying ingredients.

REPORT for June 1868.

Royal College of Chemistry,
June 25th, 1868.

SIR,

I HAVE the honour to submit to you in the following table the results of the chemical examination of the waters supplied to the metropolis during the month of June. For the purpose of comparison I append also the results yielded by Loch Katrine water, as supplied to Glasgow, and by the waters supplied to the towns of Lancaster, Manchester, Leicester, Preston, and Worthing, when submitted to the same analytical processes.

The long-continued drought has rendered the river waters supplied to London unusually pure. The previous sewage contamination of these waters is on the average much lower than has ever before been observed.

The Southwark Company's water was again turbid from the presence of much suspended matter; besides giving the water a repulsive appearance, this suspended matter is nitrogenous, and therefore highly objectionable. With the exception of the East London Company's water, which contained, however, only traces of suspended matter, the rest of the samples were perfectly bright and transparent.

I have, &c.,

The Registrar General, &c. &c. &c.

E. FRANKLAND.

ANALYSIS of the METROPOLITAN WATERS in JUNE 1868. By Professor FRANKLAND, F.R.S., of the Royal College of Chemistry.

Companies.	Date and Place of Collection.	Temperature in Centigrade degrees.	Total Solid Impurity in 100,000 parts.	Organic Carbon.	Organic Nitrogen.	Nitrogen, as Nitrates and Nitrites.	Ammonia.	Total combined Nitrogen.	Previous Sewage Contamination (estimated).	Total Hardness.
THAMES.	Temperature of Thames on 12th June	16°·6	—	—	—	—	—	—	—	—
Chelsea	18th June, Cab rank, Horse Guards	19·1	29·4	·148	·018	·113	·002	·133	820	19·7
West Middlesex	12th June, Cab rank, Portland Road	18·9	23·4	·152	·023	·096	·001	·120	650	18·4
Southwark and Vauxhall	12th June, Barclay's Brewery	15·8	30·4	·192	·046	·107	·001	·154	760	18·2
Grand Junction	15th June, Cab rank, Woodstock Street,	18·9	24·6	·170	·020	·068	·001	·089	370	19·4
Lambeth	12th June, Cab rank, Lambeth Road	17·5	24·8	·186	·022	·101	·002	·125	700	18·9
OTHER SOURCES.										
New River	12th June, Cab rank, Tottenham Court Road	18·2	24·2	·063	·015	·096	·000	·111	640	18·2
East London	12th June, Slater's Lamp Black Works, Old Ford Road	17·5	24·4	·113	·019	·055	·000	·074	230	18·2
Kent	16th June, Police Station, Greenwich	13·6	41·8	·053	·007	·434	·000	·441	4,020	27·8
Loch Katrine	February, 1867, Glasgow	—	3·28	·256	·008	·031	·002	·041	0	0·3
Lancaster	September, Lancaster	—	3·54	·157	·001	·036	·001	·038	50	0·1
Manchester	November, Manchester	—	6·80	·242	·026	·001	·001	·028	0	2·7
Leicester	November, Leicester	—	23·7	·506	·020	·001	·001	·022	0	13·4
Preston	December, Preston	—	14·7	·515	·040	·001	·003	·044	0	6·7
Worthing	November, Worthing	—	36·7	·162	·000	·426	·000	·426	3940	23·8
Column 1	2	3	4	5	6	7	8	9	10	11

The numbers in columns 4, 5, 6, 7, 8, 9, 10, and 11 all relate to 100,000 parts of the waters. The table is to be read thus: the Chelsea Company's water collected on 18th inst. at the Horse Guards' cab rank had a temperature of 19·1° C., 100,000 lbs. of it contained 29·4 lbs. of solid impurity; the organic matter, constituting a portion of this impurity, contained ·148 lb. of carbon and ·018 lb. of nitrogen. This solid impurity also contained ·113 lb. of nitrogen in the form of nitrates and nitrites, besides ·002 lb. of ammonia, whilst the total amount of *combined* nitrogen in every form was ·133 lb. The above quantity of water supplied by the Chelsea Company had been, after its descent to the earth as rain, contaminated with sewage or manure matter equivalent to 820 lbs. of average filtered London sewage.

By gradual oxidation, partly in the pores of the soil, partly in the Thames and its tributaries, and partly in the reservoirs, filters, and conduits of the company, this sewage contamination had been converted into innocuous inorganic compounds before its delivery to consumers. Finally, 100,000 lbs. of the Chelsea Company's water contained 19·7 lbs. of carbonate of lime, or an equivalent quantity of other soap-destroying ingredients.

The following is the Report for the whole year 1868:—

REPORT on the ANALYSIS of the WATERS supplied by the METROPOLITAN WATER COMPANIES during the several MONTHS of the YEAR 1868, by PROFESSOR FRANKLAND, F.R.S., &c.

Royal College of Chemistry,
January 28th, 1869.

SIR,

IN the accompanying tables I have the honour to submit to you a summary of the results of my analytical examinations of the waters supplied to the metropolis, to Edinburgh, and to certain provincial towns during the year 1868. The analytical methods which I began to employ in the previous year have been continued, and I have the satisfaction to find, that an experience extending to more than 700 different samples of water, from the most widely different sources in Great Britain, has only served to confirm my confidence in the new processes of analysis to which the metropolitan waters have, for the past two years, been submitted.

Table A. shows the temperature of the different waters as delivered from the companies' mains on the days when the samples were taken.

Table B. the amount of solid impurity left on the evaporation of 100,000 parts by weight of each sample.

Table C. the amount of carbon contained in the organic matter constituting a portion of this solid impurity (organic carbon).

Table D. the amount of nitrogen contained in the organic matter (organic nitrogen).

Table E. the amount of ammonia.

Table F. the amount of nitrogen in the form of nitrates and nitrites.

Table G. the total quantity of combined nitrogen.

Table H. the amount of previous sewage or manure contamination deduced from the amount of nitrogen in the form of nitrates, nitrites, and ammonia in excess of that contained in rain water in these forms. Nitrogenous organic matter *of animal origin* (such as that contained in the liquid and solid excrements of animals), when present in water or in the soil through which water percolates, undergoes gradual oxidation, its nitrogen becoming converted into ammonia, nitrous acid, and nitric acid, which remain in the water and constitute a record of previous sewage or manure contamination. In undergoing a similar decomposition, *vegetable* organic matter has never been observed to yield these products. I have sought for them in vain in scores of samples of water heavily contaminated with vegetable organic matter, and

taken from both springs, rivers, and surface drains. But rain-water generally contains minute traces of them amounting in the maximum to ·032 part of nitrogen in all these forms in 100,000 parts of rain-water. It is necessary therefore to deduct this amount from that found in the analysis of a sample of potable water. If there is any remainder, the water stands convicted of having been in contact with decaying animal matter. For sanitary purposes all forms of decaying animal substances may be classed as either sewage or manure matters, and all waters which have been in contact with an appreciable quantity of substances belonging to either category ought, if possible, to be rejected for domestic supply. To express this kind of contamination in terms of some known standard, I employ average filtered and fresh London sewage, which contains 10 parts of nitrogen, in the form of animal organic nitrogen, in 100,000 parts. Thus a water which yields on analysis 1·032 part of nitrogen in 100,000, as nitrous acid, nitric acid, and ammonia, contains, in 100,000 parts, the nitrogenous remains or skeleton of an amount of animal organic matter equal to that contained in 10,000 parts of average fresh filtered London sewage. Such a water is therefore said to have a previous sewage or manure contamination of 10,000 parts in every 100,000 parts.

Table I. expresses the hardness of each sample of water, that is, the number of parts of carbonate of lime (or its equivalent of other soap-destroying salts) contained in 100,000 parts of the water.

Table K. exhibits a comparison of the potable waters used in London with those supplied to Edinburgh, and some provincial towns.

The tables are to be read thus:—According to Table A., the water delivered by the Chelsea Company in January had a temperature of 7·2° Centigrade; Table B. states that 100,000 lbs. of this water contained 29·2 lbs. of solid impurity; Table C. informs us that the organic matter constituting a portion of this impurity contained ·353 lb. of carbon; Table D. that this organic matter also contained ·058 lb. of nitrogen; Table E. that 100,000 lbs. of this water contained ·001 lb. of ammonia; Table F. that ·339 lb. of nitrogen existed in the same weight of water as nitrates and nitrites; whilst Table G. shows that it contained a total of ·398 lb. of combined nitrogen in the different forms of organic matter, nitrates, nitrites, and ammonia. Table H. states that 100,000 lbs. of the water had been, after reaching the earth as rain, contaminated with sewage or manure matter equivalent to 3,080 lbs. of average filtered London sewage; and Table I. informs us that every 100,000 lbs. of this water contained 15·4 lbs. of carbonate of lime or its equivalent of other hardening salts.

The past year was distinguished by very heavy floods in the Thames basin in the winter, followed by excessive drought in summer. It was therefore to be expected that the quality of the waters of the Thames and the Lea would vary between limits unusually wide. An inspection of the accompanying analytical results shows this to have been the case. Thus the total solid impurity in Thames water varied from 22·6 to 38·6 parts in 100,000, whilst that in the Lea water ranged from 21·2 to 36 parts in 100,000. In January the Thames overflowed its banks above the point at which the metropolitan water supply is drawn, and washing the surfaces of cultivated fields, mingling with the stagnant ditches and ponds, and receiving the contents of the suddenly flushed sewers of Oxford, Reading, and Windsor, became contaminated to an intolerable degree, as evidenced by the unusually large proportion of organic carbon, organic nitrogen, and previous sewage contamination in the waters of those companies which draw from that river. It is remarkable that the quality of the water supplied from the Lea by the New River and the East London companies was but slightly affected by this flood.

On the other hand, in the summer months the waters of both rivers attained a degree of purity which I have never before observed in them. The excessive drought prevented much animal matter, both solid and liquid, from reaching the streams. The refuse was absorbed into the thirsty soil, whence it was afterwards partially dislodged by the heavy rains of October and December.

It has been frequently asserted, but without proof, that the noxious organic matter of sewage, when discharged into a river of considerable magnitude, is entirely destroyed by oxidation after a flow of a few miles. This assertion is erroneous. In his evidence before the Rivers Pollution Commission, Sir Benjamin Brodie says (First Report of Rivers Pollution Commission; Minutes of Evidence, p. 49), "I "should say that it was simply impossible, that the oxidizing power acting on sewage running in mixture with "water over a distance of any length is sufficient to remove "its noxious quality. Taking the case of Oxford, if the "sewage of Oxford was, in its entirety, discharged into the "river Thames, I should say that we could certainly not trust "to the oxidizing power to take away the noxious quality "of the water before it reaches, say, Teddington I presume "that the sewage could only come in contact with oxygen "from the oxygen contained in the water, and also from the "oxygen on the surface of the water, and we are aware that "ordinary oxygen does not exercise any rapidly oxidizing "power on organic matter. I believe that an infinitesimally "small quantity of decaying matter is able to produce an "injurious effect upon health. Therefore, if a large proportion of organic matter was removed by the process of "oxidation, the quantity left might be quite sufficient to "be injurious to health. With regard to the oxidation, we "know that to destroy organic matter the most powerful "oxidizing agents are required, we must boil it with nitric "acid and chloric acid, and the most perfect chemical agents. "To think to get rid of organic matter by exposure to the "air for a short time is absurd."

My analyses of Thames water delivered in London during the past year completely confirm Sir B. Brodie's opinion. They leave no doubt that, although oxidation does take place to some extent, a considerable proportion of the animal organic matter contained in the sewage of Oxford, Reading, Windsor, &c. reaches Teddington in an unoxidized condition.

When compared with the mean analytical results of 1867, the numbers obtained in 1868 show that the water delivered by the Chelsea, West Middlesex, Grand Junction, Lambeth, and East London companies contained slightly less solid impurity in 1868, that delivered by the New River Company contained a slight excess in 1868 (·42 part in 100,000), whilst the Southwark and Kent companies' waters exhibited a considerable increase, amounting to 2·55 and 6·03 parts respectively in 100,000. With the exception of the Lambeth, all the companies delivered water containing a greater maximum amount of solid impurity in 1868 than in 1867. The maximum amount of solid impurity in the Lambeth Company's water was the same in both years.

In every case except one the mean amount of organic carbon was much less in the past than in the previous year; the Southwark Company's water constitutes the exception; it contained only ·003 part in 100,000 less in 1868 than in 1867.

The following table exhibits a comparison of the previous sewage or manure contamination of the different waters in the two years:—

	1867.			1868.		
Thames.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.
Chelsea	3,230	1,570	2,107	3,451	350	1,858
W. Middlesex	3,290	1,050	2,069	3,360	110	1,590
Southwark	3,290	1,130	1,953	3,130	150	1,742
Grand Junction	3,160	1,050	2,036	3,340	330	1,811
Lambeth	3,150	1,260	2,144	4,050	520	1,992
Other Sources.						
New River	3,200	1,290	2,192	3,300	140	1,754
East London	3,280	230	1,610	3,400	0	1,148
Kent	4,820	2,890	3,619	5,330	3,540	3,842

The higher numbers in this table occurred in the winter, the lower in the summer months, the summer numbers being exceptionally low during the past year, owing partly to the activity of aquatic vegetation in purifying the water, and partly to the long drought, which prevented much filth from being washed into the Thames and Lea for many months.

The mean hardness of all the waters delivered in London during 1868 was greater than during 1867, with the exception of that of the Lambeth Company's water, which was 1·7° less in 1868. On the average the water delivered to consumers during the past year was nearly 1° harder than that supplied during the previous year.

I have again to call your attention to the very inefficient filtration of a considerable proportion of the water supplied to the metropolis. On several occasions the water of the Lambeth, Southwark, and Chelsea companies was in such a muddy condition as to render it totally unfit for domestic use. In February last the Lambeth Company's water was so turbid that brightly illuminated objects could not be seen through a stratum of it 12 inches deep. On account of the great amount of sewage which commingles with the river waters supplied to London, their efficient filtration before delivery is of the utmost importance.

How far this is actually accomplished by the different companies may be seen from the following table, showing the condition of the various samples when drawn from the companies' mains:—

	Number of Occasions when clear and transparent.	Number of Occasions when slightly turbid.	Number of Occasions when turbid.	Number of Occasions when very turbid.
THAMES.				
Chelsea - -	7	2	1	2
W. Middlesex -	12	0	0	0
Southwark - -	1	5	4	2
Grand Junction -	9	2	1	0
Lambeth - -	6	1	2	3
OTHER SOURCES.				
New River - -	10	2	0	0
E. London - -	3	8	1	0
Kent - - -	8	3	1	0

Of all the companies supplying London with water, the West Middlesex stands pre-eminent as regards careful filtration; not even during the early part of the year, when the Thames was excessively muddy from floods, did this company on any occasion send out water which was not perfectly clear and transparent. An inspection of Table K. shows that in other respects also the West Middlesex Company's water was superior to that of every other company drawing from the Thames. It is thus evident, that with efficient filtration Thames water can be delivered to consumers clear and transparent, even in the most unfavourable seasons.

The New River and Grand Junction companies stand next in regard to efficient filtration, whilst the Southwark Company's water is almost invariably sent out in an imperfectly filtered condition. Only on one occasion in the entire year did I obtain a sample of clear water from this company's mains, and the same was the case in 1867.

During the year the water delivered by two of the metropolitan companies exhibited for a time an exceptionally high degree of contamination. The first case was that of the Kent Company's water, which, in February and March, presented remarkable peculiarities. In February it contained no less than 59·2 parts of solid impurity in the 100,000 parts, 42 parts being the maximum and 39·3 the mean amount observed during the year 1867. Of the above 59·2 parts, 14·7 were common salt, the occurrence of which in such quantity is difficult to account for without assuming contamination from a tidal river. In March the condition of things was much worse, for the solid impurity had increased to 70·2 parts, and the common salt to 23·7 parts. The attention of the company's engineer was strongly drawn to this abnormal state of the water, and in the following month the excess of impurity disappeared.

The company's works are situated close to and on both sides of the river Ravensbourne, from which a considerable portion of the supply was formerly derived. The old reservoirs and filter beds, occupying a large area of land, sunk below the level of the Ravensbourne, are still retained, and one of them at least is used for the temporary storage of a portion of the water raised from the company's wells. The position of these reservoirs must render it very difficult to exclude percolation from the foul river, which runs within a few yards of them for a considerable distance. The remark which you made in 1866, in reference to a very similar state of things then existing at the Old Ford station of the East London Water Company, is applicable with equal force to the Kent Company's works at Deptford.

In the interests of the public health, the country has a right to demand the security which could be afforded by the filling up, and conversion into valuable land, of these old reservoirs, which the company admits are of little or no use.

The second case of exceptional contamination occurred to the Southwark Company's water during the months of August, September, and October. Drawing its supply from the same source as the other Thames companies, the Southwark Company delivered, during these months, water of a strikingly different composition. A reference to the accompanying tables B., C., and D., shows that the total solid impurity, and (in September and October) the organic constituents, were in very marked excess in this as compared with the remaining Thames waters. The proportion of common salt in Thames water delivered by the other companies during the three months above mentioned never exceeded 3·6 lbs. in 100,000 lbs. of water; whilst in the Southwark Company's water it was as follows: in August 7·5 lbs., in September 13·6 lbs., and in October 7·2 lbs. I directed the attention of the company's engineer to this abnormal condition of the water, pointing out that the admission of a certain proportion of tidal water of the Thames at Battersea, where the company's reservoirs are situated close to the river, would cause the excess of the impurities which I had observed. The exceptional contamination had been prevented when the November sample was taken, and it has not since recurred. These instances show the great importance of the analytical determination of common salt or of chloride in the London waters. Many of the companies' reservoirs are placed below high-water mark, on the banks of tidal rivers, and are, therefore, liable to percolations from the neighbouring streams, whence they formerly received their supply of water. I have, therefore, since October last added determinations of chloride to the other analytical results, and propose to continue them in my future monthly reports.

I have, &c.

The Registrar General, &c. &c. &c.

E. FRANKLAND.

Table A.

Temperature (in Centigrade degrees) of the Metropolitan Waters, as delivered from the Company's Mains.

Names of Companies.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.													
Chelsea - -	7·2	7·2	8·3	9·1	13·3	19·1	18·8	19·4	18·9	12·7	7·8	9·4	12·6
West Middlesex -	8·0	7·2	7·7	9·4	13·9	18·9	21·1	20·5	18·9	13·3	7·8	10·5	13·1
Southwark -	7·7	7·7	10·0	10·5	14·5	15·8	21·6	20·2	19·4	13·0	8·3	10·8	13·3
Grand Junction -	6·6	5·8	7·2	8·3	12·2	18·9	20·0	18·9	17·8	12·1	7·2	10·0	12·1
Lambeth -	7·2	7·2	8·6	9·4	13·6	17·5	19·4	19·4	18·6	12·7	7·2	9·7	12·5
Other Sources.													
New River -	8·0	6·6	7·5	9·4	14·1	18·2	19·5	20·5	19·1	13·3	7·2	10·3	12·8
East London -	6·4	7·2	7·2	9·7	16·1	17·5	19·4	18·9	18·3	12·7	8·3	11·1	12·7
Kent - -	7·2	11·6	10·2	11·6	13·9	13·6	16·0	13·9	13·3	12·2	10·5	11·7	12·1

Table B.

Weight of Solid Impurity in 100,000 parts of the Waters.

Names of Companies.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.													
Chelsea - -	29·2	30·8	29·0	29·4	26·4	29·4	23·0	24·8	25·4	29·2	31·2	33·0	28·40
West Middlesex -	31·4	30·0	30·2	30·8	26·4	23·4	22·6	24·0	24·4	25·6	30·2	32·5	27·62
Southwark -	32·2	32·2	32·6	29·4	26·8	30·4	23·8	30·2	38·6	33·6	30·7	32·0	31·04
Grand Junction -	31·5	32·6	28·8	29·8	25·6	24·6	23·0	24·2	24·2	29·6	31·2	33·6	28·22
Lambeth -	30·4	31·2	29·4	28·8	26·8	24·8	24·2	25·2	25·4	30·8	31·7	31·8	28·37
Other Sources.													
New River -	30·2	30·8	27·4	26·4	23·6	24·2	23·6	24·0	24·8	25·8	29·7	31·9	26·86
East London -	36·0	34·4	30·0	27·4	24·8	24·4	21·2	21·2	24·2	24·4	31·7	32·2	27·66
Kent - -	44·8	59·2	70·2	41·0	41·2	41·8	40·2	40·2	41·0	40·2	42·0	42·3	45·34

Table C.

Organic Carbon in 100,000 parts of the Waters.

Names of Companies.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.													
Chelsea - -	·353	·326	·187	·197	·190	·148	·129	·154	·142	·213	·164	·240	·204
West Middlesex -	·271	·357	·136	·178	·178	·152	·129	·133	·108	·205	·144	·239	·186
Southwark -	·485	·324	·264	·216	·195	·192	·128	·111	·194	·273	·157	·269	·234
Grand Junction -	·345	·329	·202	·170	·176	·170	·136	·137	·129	·236	·151	·257	·203
Lambeth -	·542	·360	·289	·177	·182	·186	·108	·168	·133	·225	·168	·257	·233
Other Sources.													
New River -	·115	·217	·059	·111	·072	·063	·059	·068	·045	·050	·044	·092	·083
East London -	·147	·272	·118	·099	·115	·113	·092	·115	·041	·061	·094	·096	·114
Kent - -	·064	·081	·093	·049	·053	·053	·022	·046	·014	·034	·042	·042	·049

Table D.

Organic Nitrogen in 100,000 parts of the Waters.

Names of Companies.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.													
Chelsea - -	·058	·052	·029	·021	·018	·018	·035	·021	·025	·040	·022	·034	·031
West Middlesex -	·027	·031	·012	·021	·024	·023	·025	·029	·017	·019	·017	·044	·024
Southwark -	·061	·032	·032	·027	·031	·046	·026	·023	·028	·042	·025	·036	·034
Grand Junction -	·031	·055	·027	·014	·020	·020	·024	·020	·016	·039	·024	·045	·028
Lambeth -	·062	·045	·040	·020	·024	·022	·027	·030	·020	·035	·027	·034	·032
Other Sources.													
New River -	·014	·026	·010	·013	·013	·015	·020	·017	·012	·013	·009	·016	·015
East London -	·024	·037	·022	·014	·018	·019	·023	·022	·016	·019	·021	·029	·022
Kent - -	·013	·013	·029	·008	·006	·007	·008	·006	·007	·006	·026	·012	·012

TABLE E.

AMMONIA in 100,000 parts of the WATERS.

Names of Companies.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - -	·001	·002	·003	·001	·001	·002	·002	·001	·001	·002	·000	·002	·0015
West Middlesex -	·001	·002	·001	·001	·001	·001	·002	·000	·001	·001	·000	·001	·0010
Southwark -	·001	·001	·001	·002	·001	·001	·001	·001	·001	·002	·001	·001	·0012
Grand Junction -	·000	·001	·001	·001	·002	·001	·001	·001	·001	·002	·000	·001	·0011
Lambeth -	·002	·001	·001	·001	·001	·002	·001	·000	·001	·002	·001	·001	·0012
OTHER SOURCES.													
New River -	·001	·001	·000	·000	·000	·000	·001	·001	·000	·000	·000	·001	·0004
East London -	·001	·003	·001	·001	·002	·000	·001	·001	·001	·000	·001	·002	·0012
Kent - -	·001	·001	·001	·001	·000	·000	·001	·000	·000	·000	·000	·000	·0004

TABLE F,

NITROGEN as NITRATES and NITRITES in 100,000 parts of the WATERS.

Names of Companies.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - -	·339	·340	·262	·247	·166	·113	·067	·069	·066	·337	·216	·375	·216
West Middlesex -	·367	·321	·314	·237	·167	·096	·041	·044	·075	·159	·177	·282	·190
Southwark -	·323	·344	·246	·222	·150	·107	·046	·089	·122	·227	·260	·326	·205
Grand Junction -	·366	·343	·278	·230	·161	·068	·066	·064	·088	·267	·297	·317	·212
Lambeth -	·336	·310	·248	·236	·149	·101	·109	·084	·106	·435	·277	·372	·230
OTHER SOURCES.													
New River -	·361	·355	·256	·253	·172	·095	·045	·087	·152	·190	·184	·334	·207
East London -	·307	·370	·231	·156	·016	·055	·000	·094	·033	·075	·213	·214	·139
Kent - -	·408	·564	·399	·416	·386	·434	·398	·398	·387	·396	·396	·402	·415

TABLE G.

TOTAL COMBINED NITROGEN in 100,000 parts of the WATERS.

Names of Companies.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - -	·398	·394	·293	·269	·185	·133	·104	·091	·092	·379	·238	·411	·249
West Middlesex -	·395	·354	·327	·259	·192	·120	·068	·073	·093	·179	·194	·327	·215
Southwark -	·385	·377	·279	·251	·182	·154	·073	·113	·151	·271	·286	·363	·240
Grand Junction -	·397	·399	·306	·245	·183	·089	·091	·085	·105	·308	·321	·363	·241
Lambeth -	·400	·356	·289	·257	·174	·125	·137	·114	·127	·472	·305	·407	·264
OTHER SOURCES.													
New River -	·376	·382	·266	·266	·185	·111	·066	·105	·164	·203	·193	·351	·222
East London -	·332	·410	·254	·171	·036	·074	·024	·027	·050	·094	·235	·245	·163
Kent - -	·422	·578	·429	·425	·392	·441	·407	·404	·394	·402	·422	·414	·427

TABLE H.

PREVIOUS SEWAGE or MANURE CONTAMINATION in 100,000 parts of the WATERS.

Names of Companies.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - -	3,080	3,100	2,320	2,160	1,350	820	370	380	350	3,070	1,840	3,451	1,858
West Middlesex -	3,360	2,910	2,830	2,060	1,360	650	110	120	440	1,280	1,450	2,513	1,590
Southwark -	2,920	3,130	2,150	1,910	1,190	760	150	580	910	1,970	2,290	2,945	1,742
Grand Junction -	3,340	3,120	2,470	1,990	1,310	370	350	330	570	2,370	2,650	2,863	1,811
Lambeth -	3,050	2,790	2,170	2,050	1,180	700	780	520	750	4,050	2,458	3,404	1,992
OTHER SOURCES.													
New River -	3,300	3,240	2,240	2,210	1,400	640	140	560	1,200	1,580	1,520	3,025	1,754
East London -	2,760	3,400	1,990	1,250	0	230	0	0	20	430	1,820	1,879	1,148
Kent - -	3,770	5,330	3,680	3,650	3,540	4,020	3,670	3,660	3,550	3,700	3,640	3,700	3,842

Table I.

Degrees of Hardness (1 deg. = 1 part of carbonate of lime, or its equivalent,) in 100,000 parts of the Waters.

Names of Companies.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.													
Chelsea	15·4	18·8	18·5	21·1	19·7	19·7	17·4	19·4	18·3	21·6	23·9	23·2	19·75
West Middlesex	17·3	18·4	21·4	21·1	18·8	18·4	16·4	19·2	17·4	19·4	24·5	23·7	19·58
Southwark	17·5	19·7	19·7	21·4	18·3	18·2	18·2	18·2	21·4	19·5	24·3	23·2	19·97
Grand Junction	19·7	21·1	18·5	21·1	18·0	19·4	17·5	19·2	16·5	20·8	24·8	23·7	20·02
Lambeth	16·5	18·5	18·3	20·8	18·3	18·9	17·5	19·4	18·6	20·6	24·5	22·1	19·50
Other Sources.													
New River	20·5	20·5	18·5	20·0	17·4	18·2	18·2	19·2	18·0	21·1	23·0	25·4	20·00
East London	22·8	20·5	20·5	18·9	16·6	18·2	16·2	15·1	17·9	19·3	23·8	24·8	19·55
Kent	26·2	30·0	32·3	28·5	27·1	27·8	26·2	27·1	27·1	27·0	31·3	30·3	28·41

Table K.

Comparison of the London with some Non-Metropolitan Waters.

The Numbers in this Table relate to 100,000 parts of each Water.

Name of Water.	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Nitrogen, as Nitrates and Nitrites.	Ammonia.	Total combined Nitrogen.	Previous Sewage or Manure Contamination.	Hardness.	Soap destroyed.
Thames.									
Chelsea	28·40	·204	·031	·216	·001	·249	1858	19·75	237·00
West Middlesex	27·62	·186	·024	·190	·001	·215	1590	19·58	234·96
Southwark	31·04	·234	·034	·205	·001	·240	1742	19·97	239·64
Grand Junction	28·22	·203	·028	·212	·001	·241	1811	20·02	240·24
Lambeth	28·37	·233	·032	·230	·001	·264	1992	19·50	234·00
Other Sources.									
New River	26·86	·083	·015	·207	·000	·222	1754	20·00	240·00
East London	27·66	·114	·022	·139	·001	·163	1148	19·55	234·60
Kent	45·34	·049	·012	·415	·000	·427	3842	28·41	340·92
Non-Metropolitan.									
Glasgow, from Loch Katrine	3·00	·161	·011	·000	·001	·012	0	0·30	3·60
Lancaster, from Bleasdale Fells	4·58	·129	·022	·000	·001	·023	0	0·87	10·44
Manchester, from Derbyshire hills	6·20	·183	·009	·025	·006	·039	0	3·70	44·40
Edinburgh — Crawley Burn	11·28	·187	·031	·000	·001	·032	0	6·08	72·96
Edinburgh — Coniston Water	22·58	·085	·017	·744	·001	·762	7124	10·36	124·32
Edinburgh — Swanston	12·70	·378	·059	·000	·001	·060	0	6·22	74·64
Edinburgh — Colinton	14·10	·203	·042	·000	·000	·042	0	9·17	110·04
Preston, from Longridge Fells	12·44	·236	·031	·000	·006	·036	0	8·94	107·28
Worthing, from Chalk Wells	32·44	·007	·000	·4204	·002	·4222	3902	24·69	296·28
Carlisle, from River Eden	13·1	·233	·037	·000	·001	·038	0	8·73	104·76
Norwich	28·18	·227	·055	·000	·000	·055	0	23·68	284·16
Cockermouth, from River Cocker	4·62	·069	·022	·000	·001	·023	0	2·16	25·92
Maryport, from River Derwent	6·00	·210	·041	·000	·004	·044	0	3·37	40·44
Keswick, from Skiddaw	4·34	·132	·024	·000	·001	·025	0	3·37	40·44
Banbury, from River Cherwell	36·60	·382	·054	·2304	·003	·2874	2009	24·15	289·80
Whitehaven, from Ennerdale Lake	2·16	·042	·017	·000	·000	·017	0	1·45	17·40

AVERAGE NUMBER of HOUSES, &c., supplied by the several LONDON WATER COMPANIES during the Year 1868; the AVERAGE DAILY SUPPLY of WATER in Gallons, in Cubic Metres* for all purposes, in Cubic Metres for Domestic purposes, and the Number of Decalitres† supplied to each House. (Compiled from Returns furnished by the several Water Companies during the Year.)

Water Companies.	Average Number of Houses supplied during the Year.	Average Daily Supply of Water during the Year in			
		Gallons.‡	Cubic Metres.‡	Cubic Metres for Domestic purposes (estimated).	Decalitres for Domestic purposes daily to each House.
Total	453,230	99,892,311	453,857	373,000	82·3
From Thames	206,313	51,244,763	232,828	191,349	92·7
From Lea and other Sources	246,917	48,647,548	221,029	181,651	73·6
FROM THAMES.					
Chelsea	27,072	8,388,533	38,113	31,323	115·7
West Middlesex	38,176	8,831,460	40,125	32,977	86·4
Southwark and Vauxhall	71,542	14,483,241	65,804	54,081	75·6
Grand Junction	28,838	9,834,179	44,681	36,721	127·3
Lambeth	40,685	9,707,350	44,105	36,247	89·1
FROM LEA AND OTHER SOURCES.					
New River	114,724	23,265,000	105,704	86,872	75·7
East London	95,860	18,118,972	82,323	67,656	70·6
Kent	36,333	7,263,576	33,002	27,123	74·6
Columns	1	2	3	4	5

Note.—According to returns of the London Water Companies made to the Select Committee on East London Water Bills (Session 1867), it is estimated that during the year 1866, on an average, 82·18 per cent. of the total average daily supply of water for all purposes was for domestic use; the proportions supplied for the year 1866 have been applied in estimating the quantities for the year 1868 in column 4, showing the cubic metres probably used for domestic purposes.

The average daily quantity of water supplied by the London Companies during the year 1868 was 99,892,311 gallons (453,857 cubic metres, equal to about as many *tuns* by measure, *tons* by weight), of which about 82,095,838 gallons (373,000 cubic metres) were probably used for domestic purposes. The quantity used for house supply daily was 82·3 decalitres to each house, and 11·6 decalitres (=25·53 gallons) to each person.

* A cubic metre is equal in volume to 35·3174 cubic feet, or to 220·0967 imperial gallons. It is nearly equivalent to the old English *tun* of four hogsheads, holding 35·248 cubic feet. It is in general use on the Continent; and its volume of water weighs a metric ton, differing inconsiderably in weight from the ton in common use.

† One gallon equals ·4543458 of a decalitre.

‡ The quantities of water in columns 2 and 3 include the supply for manufactures and for various purposes other than for domestic consumption.

The water companies in their returns reckon uninhabited as well as inhabited houses.

APPENDIX AK.

REPORT from PROFESSOR WANKLYN, on the QUALITY of the WATER supplied in the METROPOLIS.

London Institution,
June 20, 1868.

SIR,

THE result of a prolonged examination carried out by myself, Mr. Chapman, and Mr. Smith, on the Water Supply of London, Manchester, Glasgow, and Edinburgh, last summer, is the following:—

The water of the Thames at Hampton Court, where the Companies draw their supply of Water, is not very good, as it exists in the river; but after the filtration effected by *some* (but not all) of the Companies, it becomes excellent, and in point of purity from organic nitrogenous matter is then fully equal to the water supplied to Manchester, Edinburgh, or Glasgow.

The water supplied by the New River Company is also very good.

Very truly yours,

W. Pole, Esq. (Signed) J. A. WANKLYN.

DIAGRAM

Shewing the Increase of

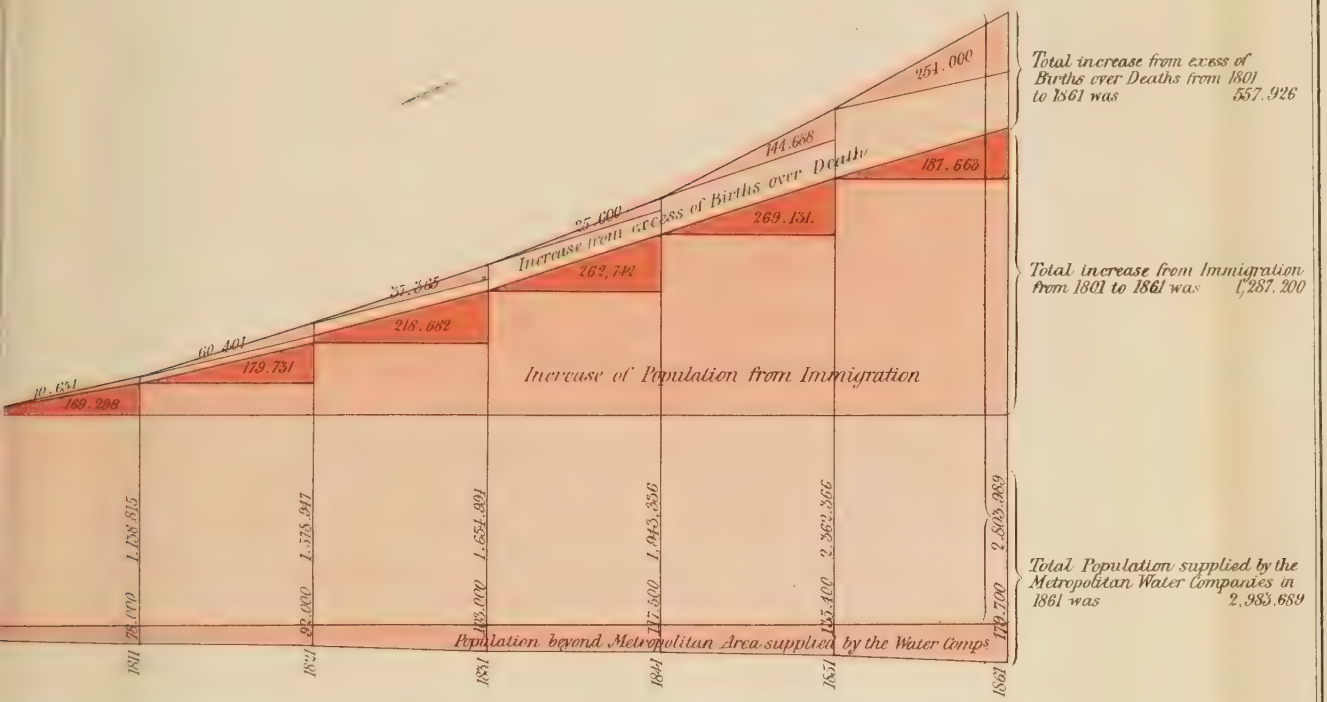
POPULATION OF THE METROPOLIS WITHIN THE REGISTRATION DISTRICTS.

From 1801 to 1861,

AND OF THE DISTRICTS BEYOND THE METROPOLITAN AREA

Which are Supplied by the

METROPOLITAN WATER COMPANIES.



		Excess of Birth over Deaths	Increase from Immigration.
From 1801. to	1811.	1·1 p. cent	17·7 p. cent.
„ 1811. „	1821.	5·3 „	15·7 „
„ 1821. „	1831.	2·7 „	15·8 „
„ 1831. „	1841.	1·6 „	15·8 „
„ 1841. „	1851.	7·4 „	13·8 „
„ 1851.	1861	10·7 „	7·9 „

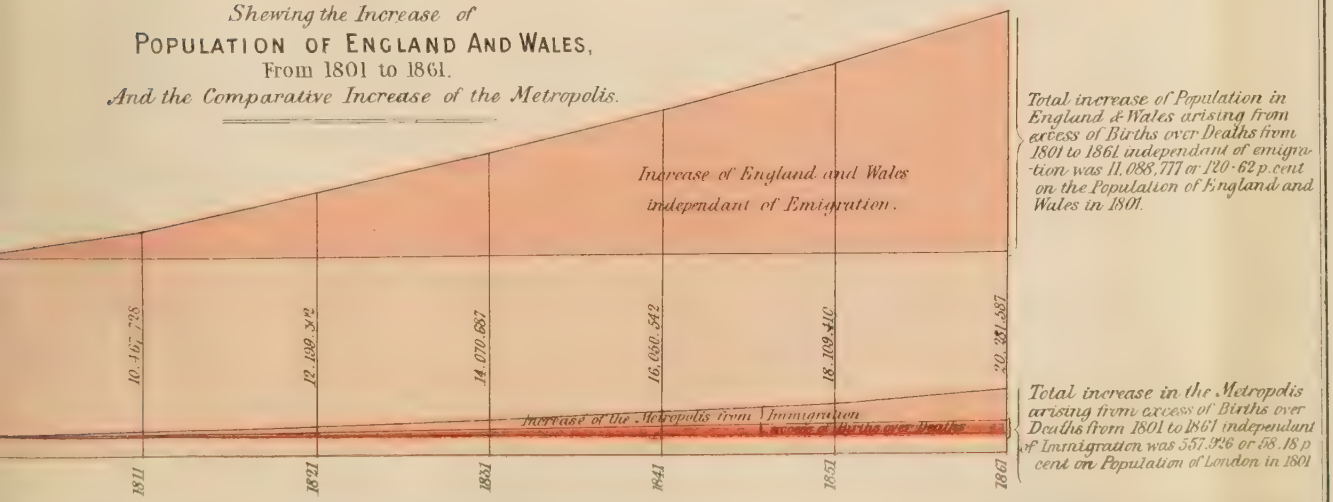
DIAGRAM

Shewing the Increase of

POPULATION OF ENGLAND AND WALES,

From 1801 to 1861.

And the Comparative Increase of the Metropolis.


Total increase of Population in England & Wales arising from excess of Births over Deaths from 1801 to 1861 independant of emigration was 11,088,777 or 120·62 p. cent on the Population of England and Wales in 1801.
Increase of England and Wales independant of Emigration.
Total increase in the Metropolis arising from excess of Births over Deaths from 1801 to 1861 independant of Immigration was 557.926 or 58.18 p cent on Population of London in 1801
Increase of the Metropolis from Immigration
Excess of Births over Deaths
10.167.738
12.139.342
14.070.687
16.050.342
18.709.410
20.251.887
1811
1821
1831
1841
1851
1861

N.B. This includes the excess of Births over Deaths of the Children of Immigrants as well as of those of the Inhabitants of London in 1801.

Remark of Register General in Vol. I. Part I. Page CVI. Census of 1851

"Only 645.000 Men and Women would be left in London if the 750.000 recruits marched back to their homes."

Appendix A.I.(2)

DIAGRAM

Shewing the Increase of the

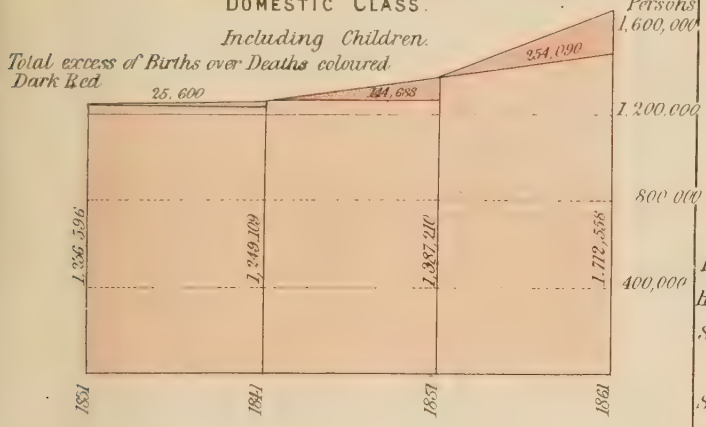
DOMESTIC, INDUSTRIAL & OF THE LEARNED & WEALTHY CLASSES

of London from 1831 to 1861.

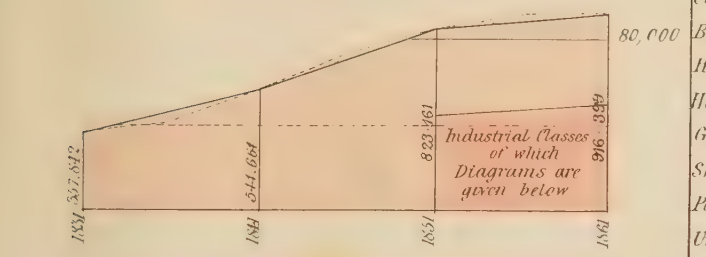
DOMESTIC CLASS.

Including Children.

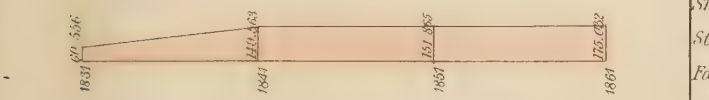
Total excess of Births over Deaths coloured Dark Red



INDUSTRIAL CLASS.



LEARNED & WEALTHY CLASS.



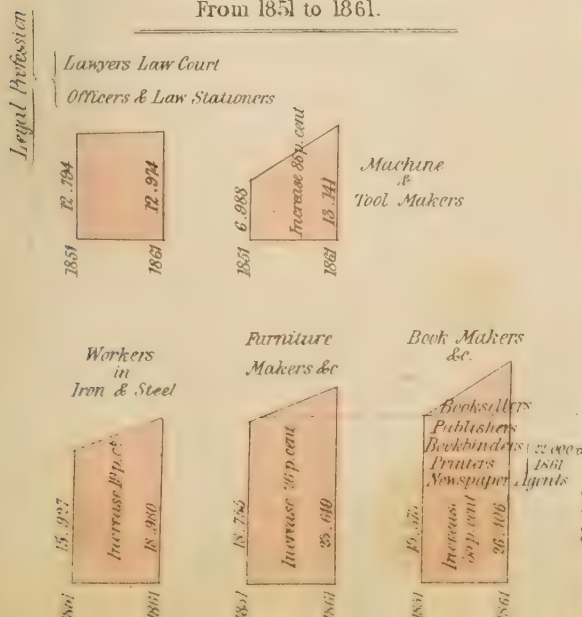
DIAGRAM

Shewing the Increase in the

NUMBER OF THE LEGAL PROFESSION

AND OF THE MOST IMPORTANT INDUSTRIAL CLASSES,

From 1851 to 1861.



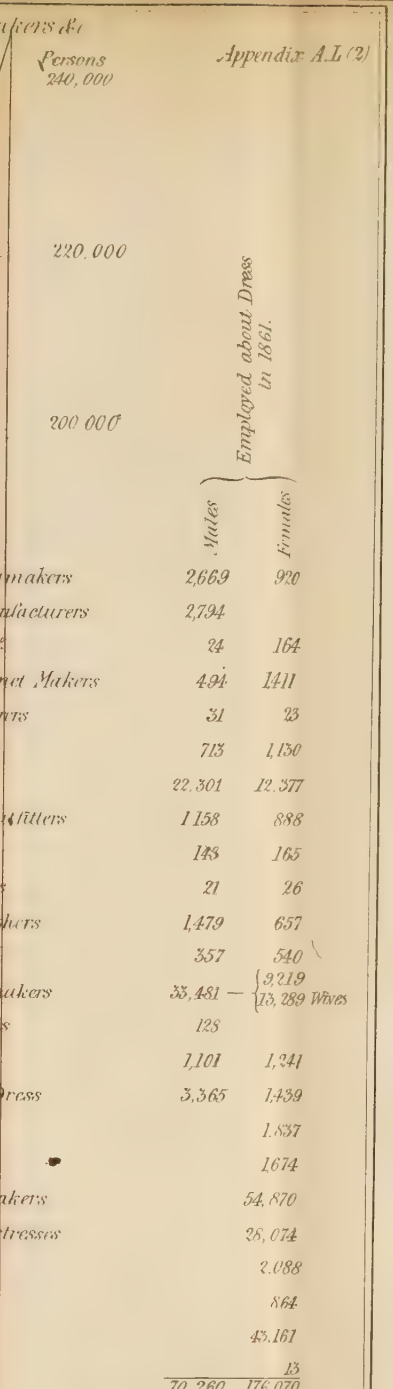


DIAGRAM.

Shewing approximately the increase of

POPULATION OF THE DISTRICTS SUPPLIED BY THE METROPOLITAN WATER COMPANIES

from 1801 to 1861.

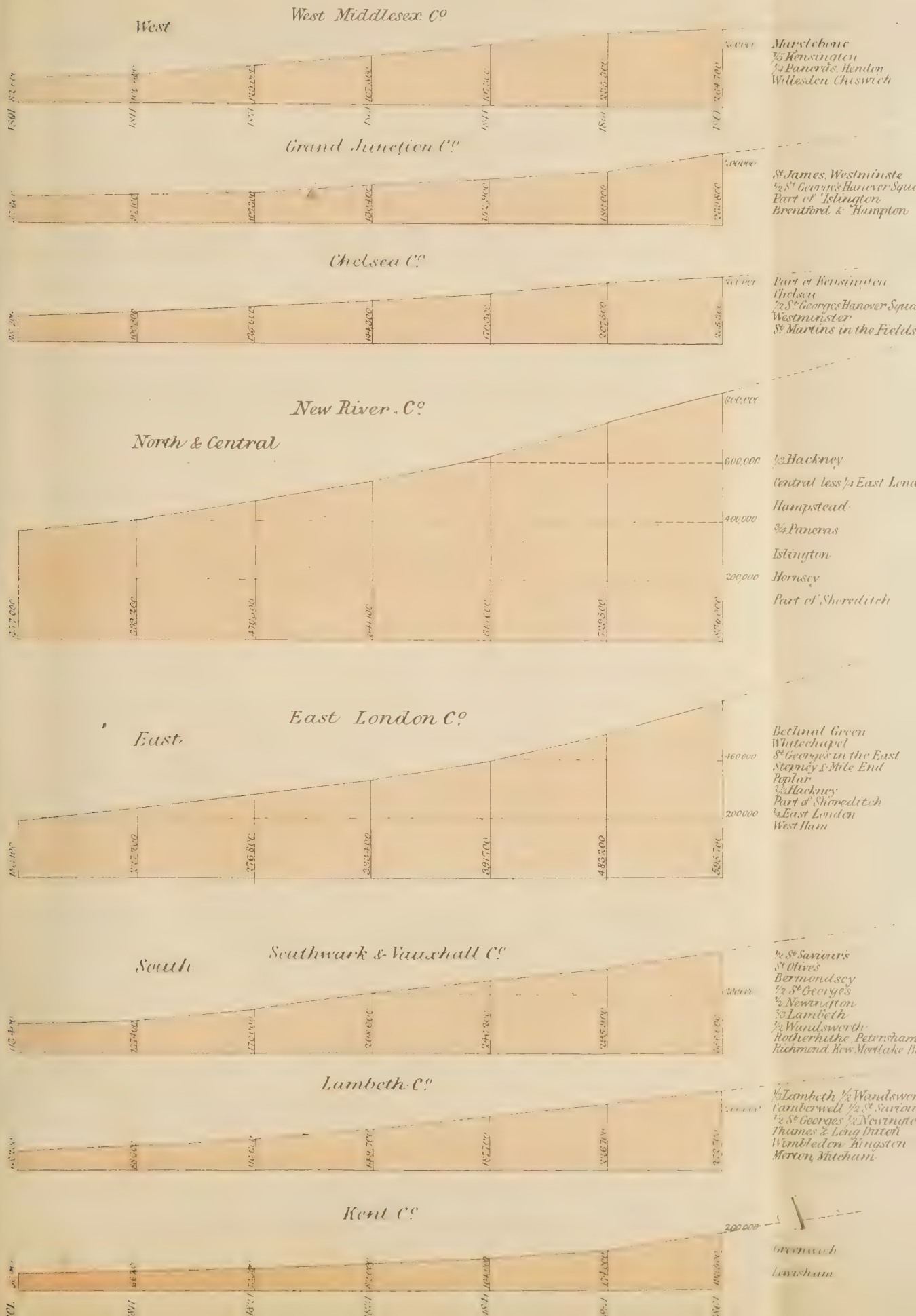
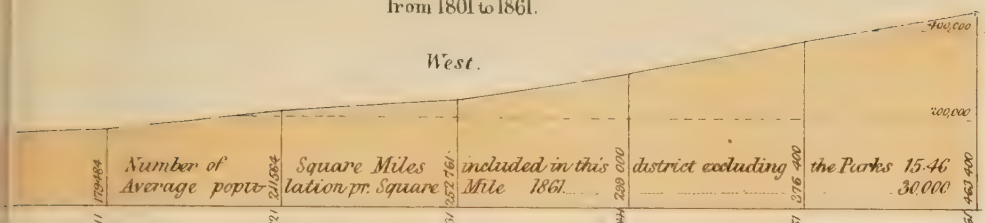


DIAGRAM.

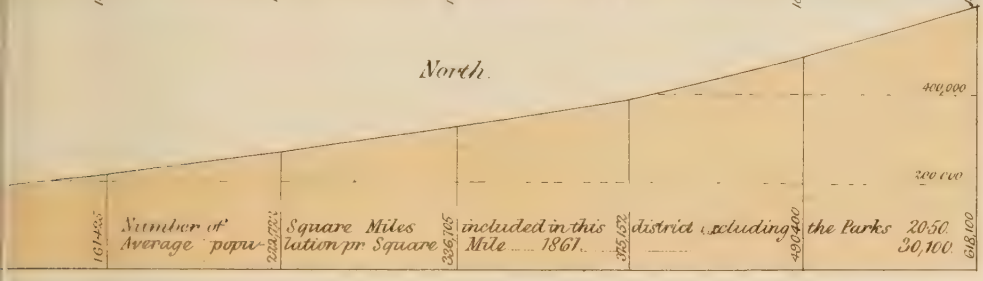
Shewing the increase of

POPULATION IN THE METROPOLITAN DISTRICTS

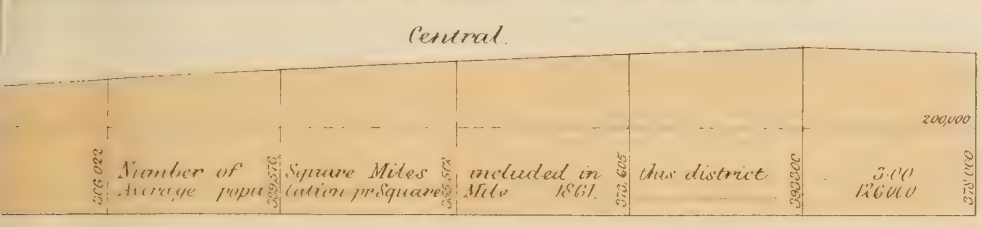
from 1801 to 1861.



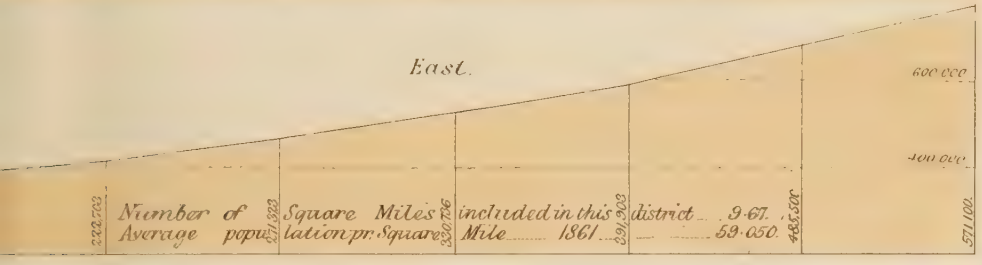
	Popn 1861	Area in Sq. Miles	Popn to Sq. Mile in 1861
Kensington (Kensington 70·105 / Fulham 10·056 / Paddington 5·390)	185,350	1130	46,384
Chelsea	63,433	130	48,800
St George's Hanover Square	87,771	130	67,500
Westminster	68,213	103	66,226
St Martins	22,689	28	81,032
St James Westminster	36,326	25	41,304
	463,588	1546	



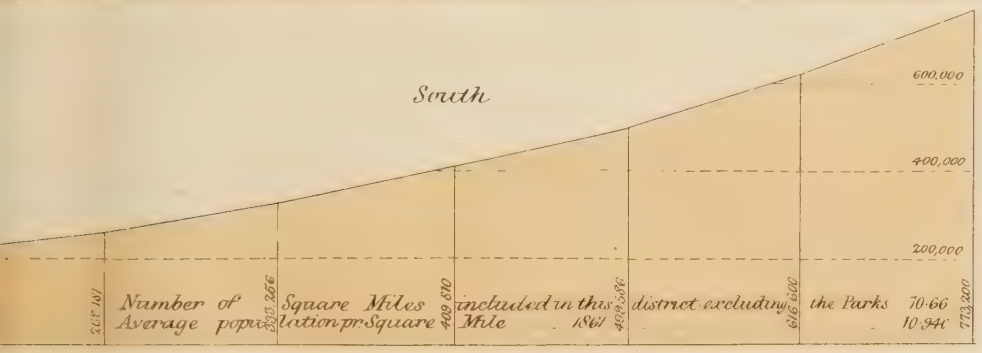
Mary le bone	101,680	186	86,924
Hampstead	19,106	3·51	5,448
Pancras	198,788	4·10	48,460
Islington	135,341	4·30	31,702
Hackney	83,295	6·13	13,588
	618,210	2050	



St Giles, Strand	54,076	38	132,305
	42,978	07	160,000
Holborn, Clerkenwell	44,862	20	112,340
	65,681	59	111,323
St Lukes, East London	57,073	34	167,856
	40,687	33	123,290
West London, City of London	27,145	31	120,511
	45,555	68	67,375
	378,057	3·00	



Shoreditch	129,564	1·00	129,564
Bethnal Green	105,101	1·20	88,500
Whitechapel	78,970	0·3	237,540
St George's in the East	48,891	38	128,660
Stepney	56,577	90	62,857
Mile End Old Town	73,064	1·66	68,900
Poplar	79,196	4·34	17,599
	571,158	9·67	



St Saviour	36,170	39	92,743
St Olave	19,056	26	73,292
Bermondsey	58,365	1·07	54,537
St George's	55,510	44	126,159
Newington	82,220	97	84,762
Lambeth	162,044	6·27	25,842
Wandsworth	70,402	18·20	3·900
Camberwell	71,488	6·70	10,669
Rotherhithe	24,502	1·38	17,755
Greenwich	127,670	8·08	15,800
Lewisham	65,757	26·30	2,440
	773,715	10·60	

RAM SHEWING THE INCREASE OF POPULATION OF THE DISTRICTS BEYOND THE METROPOLITAN.

AREA SUPPLIED BY THE WATER COMPANIES. *Same Scale as the above diagram.*

Hendon, Willesden, Chiswick.

Acton, Ealing, Hanwell, Brentford, Hounslow, Isleworth Twickenham, Hampton

Hornsey.

Stratford le Bow West Ham, Leyton

Petersham, Richmond, Kew Mortlake Barnes

Kempton, Thames Ditton, Long Ditton

APPENDIX A.M.

PARTICULARS of WATER SUPPLIES to various PROVINCIAL TOWNS.

APPENDIX AM.

PARTICULARS of WATER SUPPLIES to various

Name of Town.	Population in 1861.	Source of Supply.	Whether supplied by Gravitation or Pumping.	Area of Gathering Ground (if any).	Whether Constant or Intermittent Supply.	Whether Works in hands of Private Company or Corporation.
Nottingham	130,000	Chief supply from wells in red sandstone, and part from River Trent by natural filtration.	First pumped, then by gravitation; part supplied from main on way to reservoir.	- -	Constant -	Private company
Bristol -	116,280	Springs at Chewton, Mendip, Harptree Combe, and Barrow Gurney, and from River Kenn at Chelvey.	Gravitation; a small portion pumped 140 feet to elevated reservoir for service of high ground at Clifton, &c. Auxiliary supply pumped from River Kenn to gravitation reservoirs, 350 feet high.	- -	Constant, with power to shut off.	Private company
Preston -	82,262	Collecting ground at Longridge.	Gravitation - -	- -	Constant -	Corporation -
Dundee -	90,000	Surface collection - -	Gravitation - -	- -	Constant -	Private company
Norwich -	53,000	River Wensom - -	First pumped, then by gravitation; small part supplied from main on way to reservoir.	- -	Constant -	Private company
Leicester -	52,420	Thornton watershed -	Gravitation -	- -	Constant -	Private company
Derby -	37,496	Springs from sandstone, and water from River Derwent obtained by natural filtration.	First pumped, and then by gravitation.	- -	Constant -	Private company
Croydon -	29,838	Wells in the chalk - -	First pumped, and then by gravitation; but town is partly supplied from main on way to reservoir.	- -	Intermittent, on 11 hours out of 24.	Local Board of Health.
Liverpool -	600,000	Wells and impounded water, the former in the immediate neighbourhood of Liverpool, and the latter at a distance from 24 to 31 miles.	Gravitation and pumping from wells to reservoirs, thence by gravitation.	- -	Intermittent on 15 hours, off 9 hours.	Corporation -
Glasgow -	490,308	Loch Katrine and the Gorbals	Gravitation - -	- -	Constant -	Corporation -
Manchester	459,968	Collecting grounds and mountain springs at Woodhead, and the River Etheron near its rise.	Gravitation - -	- -	Constant -	Corporation -
Leeds -	222,240	Collecting grounds at Eccup, and pumping from River Wharfe.	Part gravitation, part pumping into reservoirs; then by gravitation to town.	- -	Constant -	Corporation -
Edinburgh	202,185	Collecting grounds on the Pentland Hills, and springs at Crawley and other places.	Gravitation - -	- -	Constant -	Private company
Sheffield -	198,850	Off the moors at Redmires. New source, Loxley watershed.	Gravitation - -	- -	Intermittent, 12 hours per day.	Private company
Newcastle-on-Tyne.	160,000	Collecting grounds and streams at Hallington and Whittle Dean, and water is also pumped at Newburn from the Tyne.	Part gravitation, part pumped into reservoirs.	- -	Constant -	Private company
Sunderland and South Shields.	150,000	Wells - - -	Pumped into reservoir, then gravitation.	- -	Constant -	Private company

NOTE.—The figures under the head of "Population in 1861" represent

APPENDIX AM.

PROVINCIAL TOWNS.—Furnished by Mr. SIMPSON.

Whether compulsory or optional Rating.	If the former, what Rates are actually charged.	Average Daily Consumption for			Total daily Supply. Gallons.	Consumption per Head.	
		Town Purposes. Gallons.	Manufactures. Gallons.	Domestic Purposes. Gallons.		Total. Gallons.	For Domestic Purposes. Gallons.
- - - -	- - - -	48,201	586,250	1,710,549	2,345,000	18·40	13·16
- - - -	- - - -	—	236,767	1,934,753	2,171,520	18·67	16·64
- - - -	- - - -	—	465,753	1,534,247	2,000,000	24·38	18·65
- - - -	- - - -	No data.	No data.	No data.	2,340,000	26·00	—
- - - -	- - - -	32,710	115,804	619,986	768,500	14·50	11·71
- - - -	- - - -	26,568	333,802	739,630	1,100,000	20·98	14·11
- - - -	- - - -	32,098	156,120	567,490	755,708	20·15	15·14
- - -	- - - -	No account kept.	16,428	1,183,572	1,200,000	40·22	39·67
- - - -	- - - -	647,945	1,556,164	15,795,891	18,000,000	30·00	26·33
- - - -	- - - -	No account kept.	3,000,000	21,740,000	24,740,000	50·45	44·34
- - - -	- - - -	90,410	1,842,063	8,716,143	10,648,616	23·15	18·95
- - - -	- - - -	None used.	750,000	3,550,000	4,300,000	19·34	15·97
- - - -	- - - -	19,042	904,398	5,476,560	6,400,000	31·65	27.09
- - - -	- - - -	No flushing sewers.	493,150	2,506,850	3,000,000	15·08	12·60
- - - -	- - - -	106,849	1,343,750	3,924,401	5,375,000	33·59	24·53
- - - -	- - - -	42,371	943,190	1,954,287	2,939,848	19·59	13·03

the estimated number of inhabitants supplied with water in each town.

PARTICULARS of WATER SUPPLIES in various

Name of Town.	Population now Supplied, May 1868.	Source of Supply.	Whether supplied by Gravitation or Pumping.	Area of Gathering Ground (if any).	Whether constant or intermittent Supply.	Whether Works in Hands of Private Company or Corporation.
				Acres.		
Glasgow -	511,000	Loch Katrine and Gorbals -	Gravitation - - -	48,360	Constant -	Corporation -
Manchester	600,000	River Etherow and tributary streams and springs.	„ „	19,000	„ „	„ „
Liverpool -	600,000*	Wells and Rivington hills near Bolton.	Both - - - -	10,000	At present intermittent.	„ „
Edinburgh	206,117	Pentland Hills - -	Gravitation - - -	18,000	Constant -	Private company
Bradford -	203,000†	Valleys of the rivers Aire and Wharfe.	„ „	10,650	„ „	Corporation -
Newcastle-on-Tyne.	200,000	Reservoirs at Whittle Dean and river Tyne.	Both - - - -	17,300	„ „	Private company
Wolverhampton.	60,000‡	River Worfe at Cosford and Wells in new red sandstone.	Pumping - - -	—	Greater portion *constant*, remainder *intermittent*.	Corporation; only this year acquired from a private company.
Halifax -	50,000	Hills, north and west of town.	Gravitation - - -	2,600	Constant -	Corporation -
Birkenhead	52,826	Wells, new red sandstone -	Pumping - - -	—	Constant in fire mains, intermittent for repairs.	Town commissioners.
Chester§ -	31,301‖	River Dee - - - - -	„ „	—	Intermittent -	Private company

* Liverpool.—The return of the daily consumption of water is the average of the year ending
† Bradford.—The consumption per head is yearly increasing, and will probably reach 40 gallons
‡ Wolverhampton.—The return of the daily consumption for "Town purposes and manufactures"
§ Chester.—The return of the daily consumption of water is for the year 1861, since which time
‖ Population supplied in 1861.

Provincial Towns.—Furnished by Mr. Bateman.

Whether compulsory or optional Rating.	If the former, what Rates are actually charged.	Daily Consumption for			Total daily Supply. Gallons.	Consumption per Head.	
		Town Purposes. Gallons.	Manufactures. Gallons.	Domestic Purposes. Gallons.		Total Gallons.	For Domestic Purposes. Gallons.
Compulsory within the limits of the municipality.	1*d.* in the £ on the rental of all buildings, and 1*s.* in the £ for dwellings.	Not known	About 4,000,000	23,000,000	27,000,000	53	About 45
Compulsory within the limits of the municipality.	9*d.* in the £ on the poor law assessment of all dwellings, and 3*d.* in the £ on the same assessment of all property.	63,397	4,436,603	9,000,000	13,500,000	22½	15
Compulsory within the limits of the municipality.	6*d.* in the £ on the poor rate assessment (half paid by the landlord), and a *rent* of 6¾*d.* in the £ for domestic supply.	821,918	2,363,581	12,444,644	15,630,143	26·05	20·74
Optional - - -	- - - - -	1,060,030		6,360,182	7,420,212	36	30
Compulsory water rate, optional as to *use* and payment for water.	Rate varies with the deficiency of income to cover interest and expenses. This year's rate is 6*d.* in the £ in addition to the *water rent*. It has been 2*s.*	No means of separating the quantities used for these several purposes.			6,000,000	30	—
Optional - - -	- - - - -	—	1,500,000	4,000,000	5,500,000	28	21
„ „	- - - - -	454,640		1,025,804	1,480,444	19	17
„ „	According to special Act. No compulsory rates unless *rents* are insufficient to meet interest or outlay and working expenses.	—	—	—	2,250,000	45	—
No compulsory rating in district.	- - - - -	4,500	130,000	1,659,000	1,793,000	34	31½
Optional - - -	- - - - -	10,000	35,000	755,000	800,000	25·56	24·1

December 31, 1867.
per head in two or three years.
includes the quantity of water supplied in bulk to Bilston.
the population supplied and the quantity of water consumed have correspondingly increased.

Appendix AN.(1)

PLAN SHEWING

Mr BATEMAN'S

SERVICE RESERVOIRS AT EDGWARE

WITH

SERVICE AQUEDUCT AND MAINS

TO COMMUNICATE WITH THE

EXISTING DISTRIBUTION ARRANGEMENTS.

Figures in Red shew heights above Ordnance Datum.

PROPOSED

SE

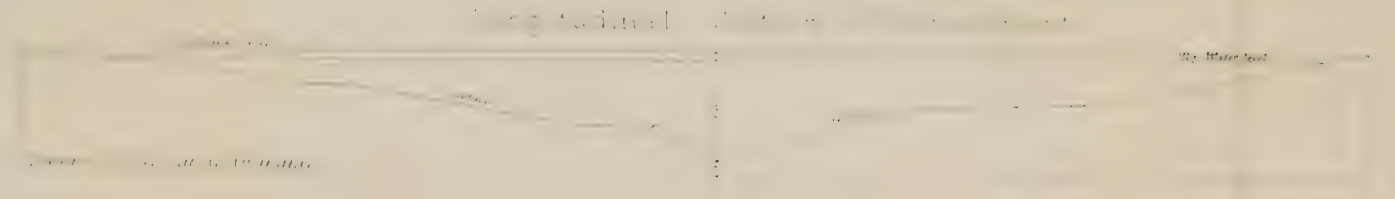
Scale of Statute Miles.

Furlongs 1 2 3 4 5 6 7 8 — 1 2 3 4 Miles

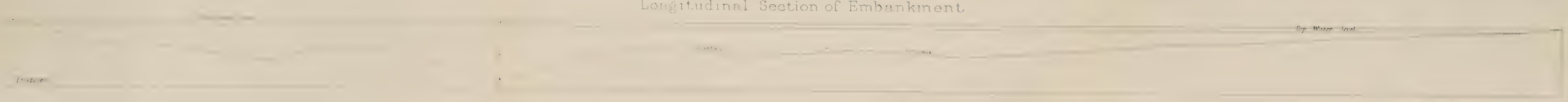
Enfield
East Barnet
Southgate
Tyrers Barnet
GREAT NORTHERN RAILWAY
Edmonton
Upper Edmonton
Chingford
The New River
Tottenham Wood Farm
Wood Green
Maswell Hill
Hornsey
Tottenham High Cross
Hanger Green
Lea and Stort Navigation
Chapel End
NORTHERN AND EASTERN RAILWAY
Crouch End 242
Pipes 4 feet diameter
Pipes 4 feet diameter
Highgate
Proposed Hornsey Reservoir 140 EAST LONDON W.W.Co
231 Maiden Lane Reservoir NEW RIVER W.W.Co
Stamford Hill
Stoke Newington
Wanstead
Leytonstone
WOODFORD BRANCH
Great Ilford
EASTERN COUNTIES RAILWAY
Little Ilford
D I S T R I C T N° I
Bonnerton
Bells Pond
BIRMINGHAM JUNCTION RAILWAY
EAST & WEST INDIA DOCKS AND
Barrow Hill Reservoir 190
Islington
VICTORIA PARK
Pumping Stat.
EAST LONDON W.W.Co
Stratford
West Ham
BOW AND BARKING RAILWAY.
BARKING
Dagenham
REGENTS PARK
Kings Cross
Bow
Bromley
East Ham
Pipes 3 feet diameter
Pipes 3 feet diameter
BLACKWALL RAILWAY
Blackwall
ST PAULS
Charing Cross
Tower
Poplar
West India Docks
River Lea
BRANCH RAILWAY
HYDE PARK
Rotherhithe
Bermondsey
GREENWICH RAILWAY
The Isle of Dogs.
Greenwich Marsh
WOOLWICH RAILWAY
Royal Arsenal
Plumstead
Abbey
Hospital
Pumping Stat.
SOUTHWARK & LAMBETH W.W.Co
Pipes 3 feet diameter
Camberwell
Peckham
GREENWICH
KENT
Blackheath
Proposed Reservoir
Kidbrooke
East Wickham
Clapham
Brixton
Clapham Common
East Dulwich
Lee
Well Hall
Eltham
Eltham Lodge
Bexley New Town
Bexley
Lambabbey
Dulwich
LONDON CHATHAM AND DOVER RAILWAY
Sydenham
Upper Tooting
Lower Norwood
197 Streatham Hill Reservoir LAMBETH W.W.Co
Tooting
Upper Norwood
Streatham
Southend
North Cray
Foots Cray
Chislehurst
Beckenham
BROMLEY
St Pauls Cray
St Mays Cray
CROYDON RAILWAY
MID KENT RAILWAY
WIMBLEDON AND CROYDON

Proposed Stanmore Reservoirs.

Reservoir N°1



Reservoir N°. 2.

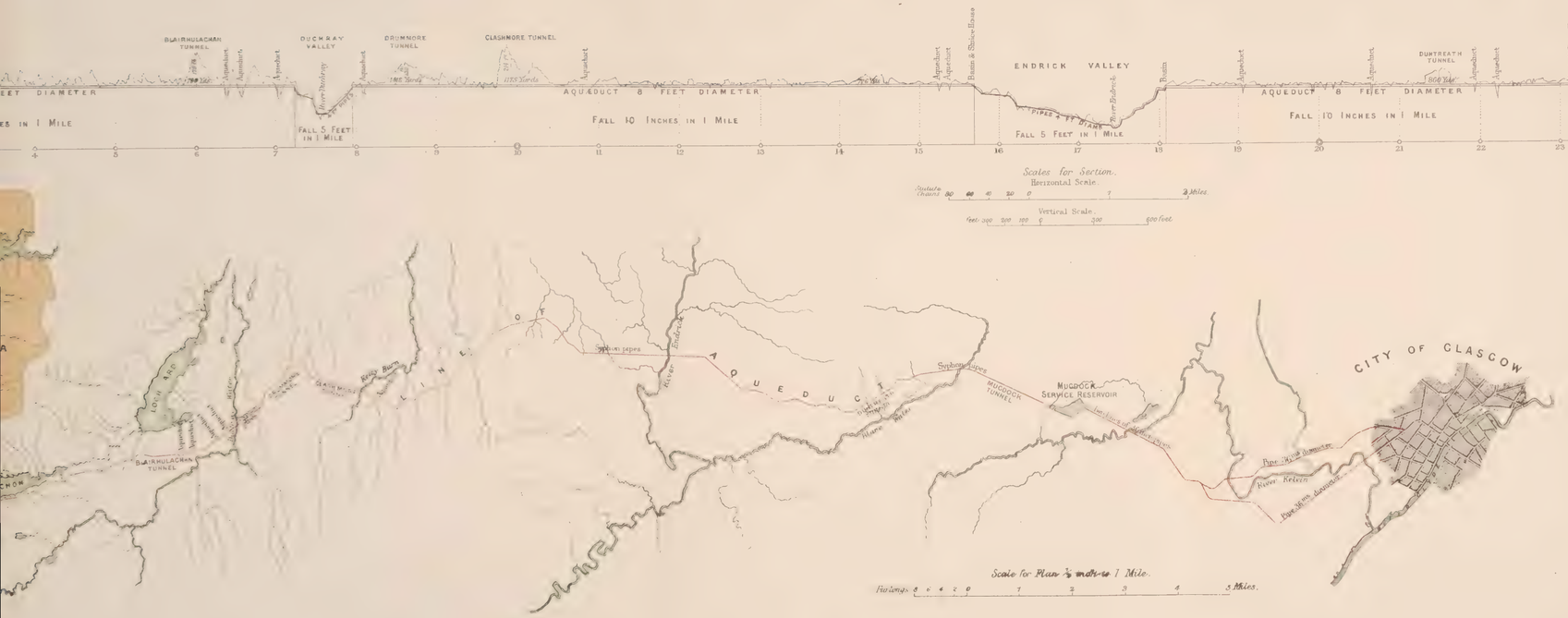


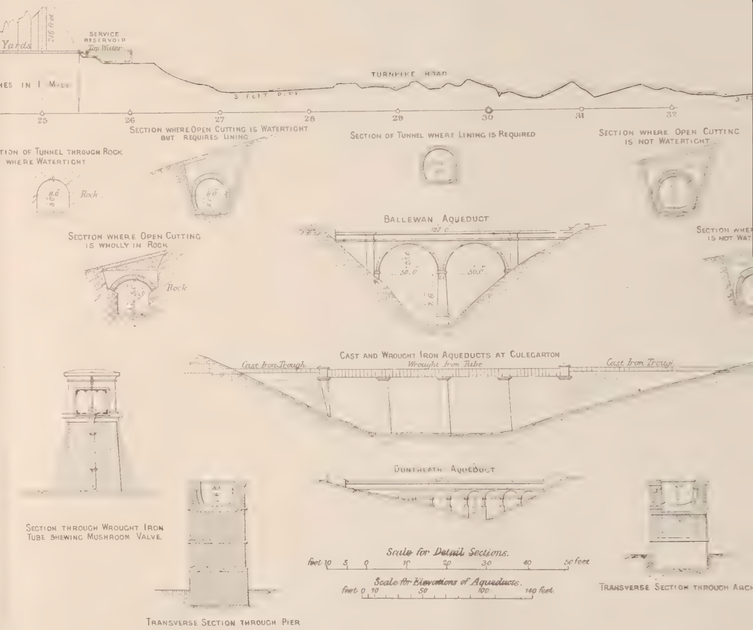
GLASGOW CORPORATION WATERWORKS.

PLAN AND SECTION OF AQUEDUCT FROM LOCH KATRINE TO GLASGOW WITH DETAILS OF CONSTRUCTION.

Commenced 1855.
Completed 1859.

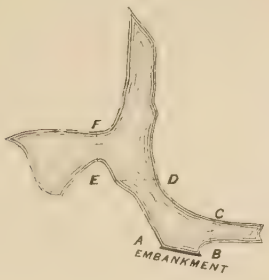
J. F. Bateman C.E. F.R.S.
Engineer



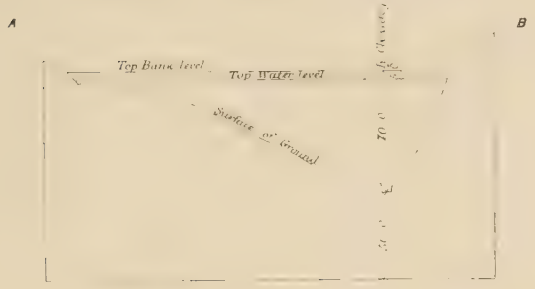

SECTION WHERE OPEN CUTTING IS WATERTIGHT BUT REQUIRES LINING
SECTION OF TUNNEL WHERE LINING IS REQUIRED
SECTION WHERE OPEN CUTTING IS NOT WATERTIGHT
SECTION OF TUNNEL THROUGH ROCK WHERE WATERTIGHT
SECTION WHERE OPEN CUTTING IS WHOLLY IN ROCK
BALLEWAN AQUEDUCT
CAST AND WROUGHT IRON AQUEDUCTS AT CULEGARTON
Cast from Trough
Wrought from Tube
DUNTREATH AQUEDUCT
SECTION THROUGH WROUGHT IRON TUBE SHEWING MUSHROOM VALVE
TRANSVERSE SECTION THROUGH PIER
TRANSVERSE SECTION THROUGH ARCH
Scale for Detail Sections.
Scale for Elevations of Aqueducts.

PROPOSED CLYWEDOG RESERVOIR.

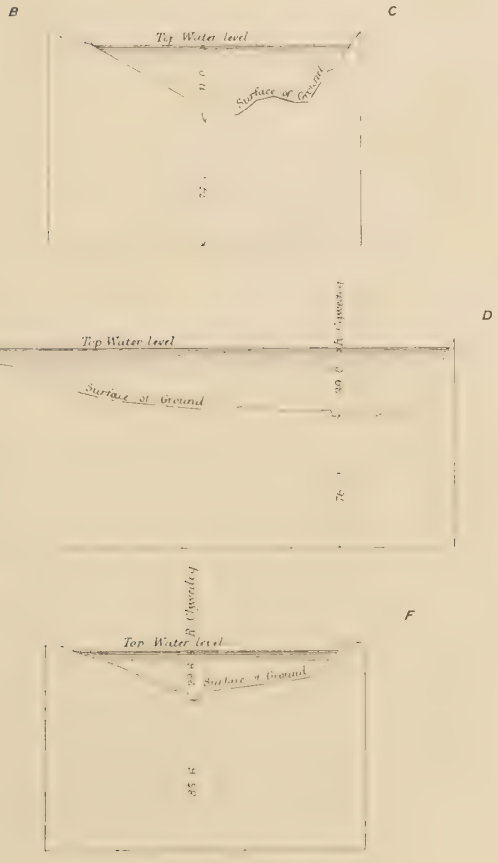
PLAN OF RESERVOIR



LONGITUDINAL SECTION OF EMBANKMENT



TRANSVERSE SECTIONS OF RESERVOIR



Scale for Plan.

furlongs 8 7 6 5 4 3 2 1 0 1 2 miles

Horizontal Scale for Sections.

feet 100 0 500 1000 1400 feet

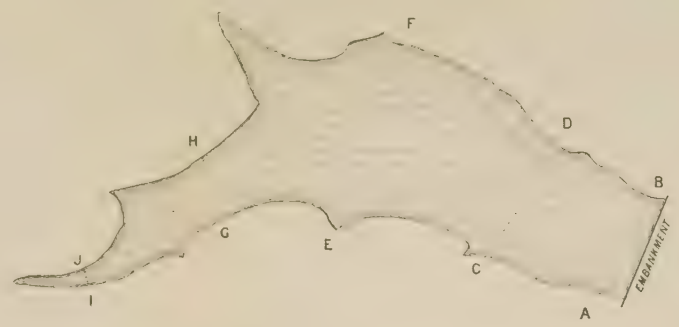
Vertical Scale for Sections.

feet 0 50 100 150 200 feet

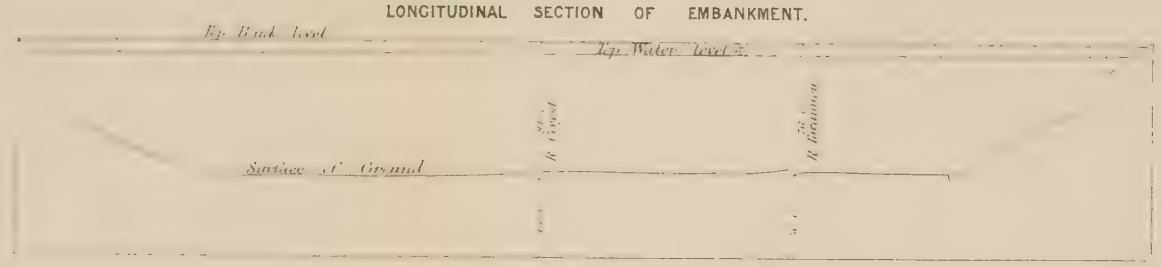
PROPOSED TREFECLWYS RESERVOIR.

Appendix A.P. 2

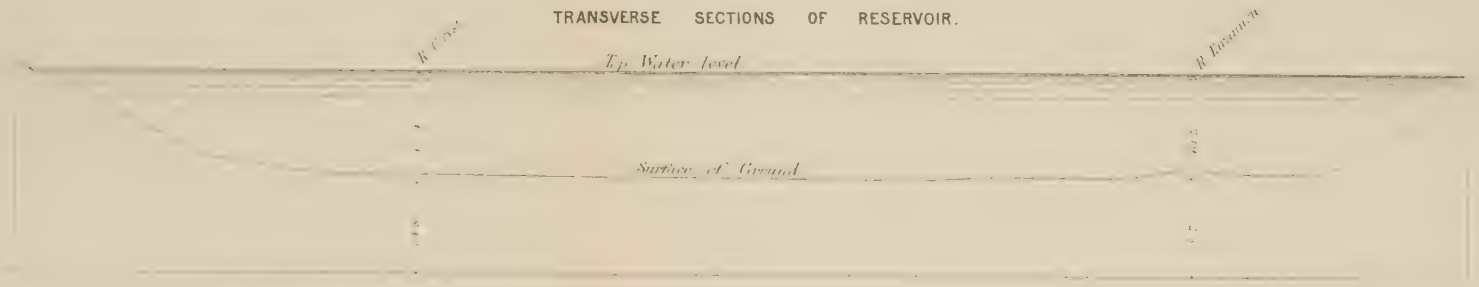
PLAN OF RESERVOIR.

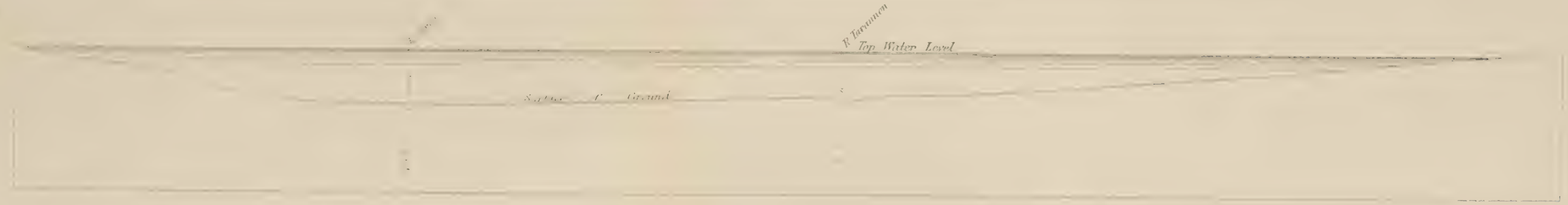


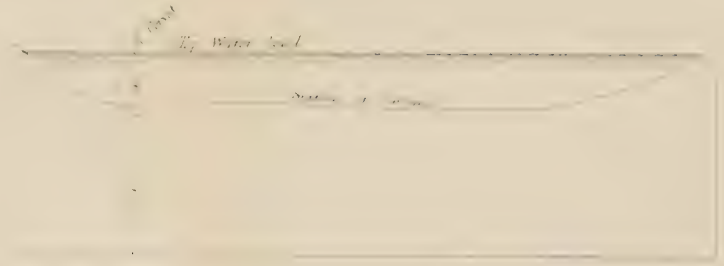
LONGITUDINAL SECTION OF EMBANKMENT.



TRANSVERSE SECTIONS OF RESERVOIR.







Scale for Plan

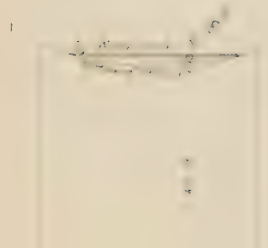
Inches 8 7 6 5 4 3 2 1 0 1 2 Miles

Horizontal Scale for Sections.

feet 500 0 500 1000 1500 feet

Vertical Scale for Sections

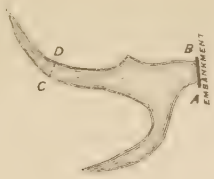
feet 0 50 100 150 200 feet



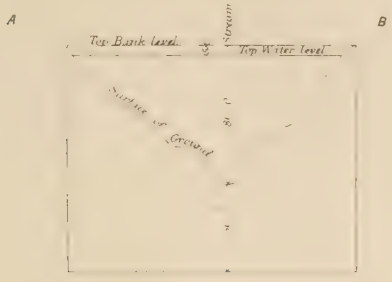
PROPOSED NANT-YR-EIRA RESERVOIR.

Appendix A1?

PLAN OF RESERVOIR



LONGITUDINAL SECTION OF EMBANKMENT

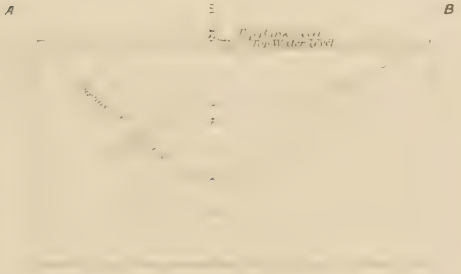


TRANSVERSE SECTION OF RESERVOIR

PROPOSED NANT-YR-EIRA UPPER RESERVOIR (IF REQUIRED)

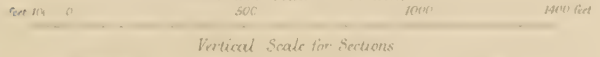
PLAN OF RESERVOIR

LONGITUDINAL SECTION OF EMBANKMENT

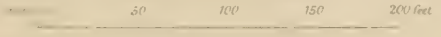


Scale for Plans

Horizontal Scale for Sections



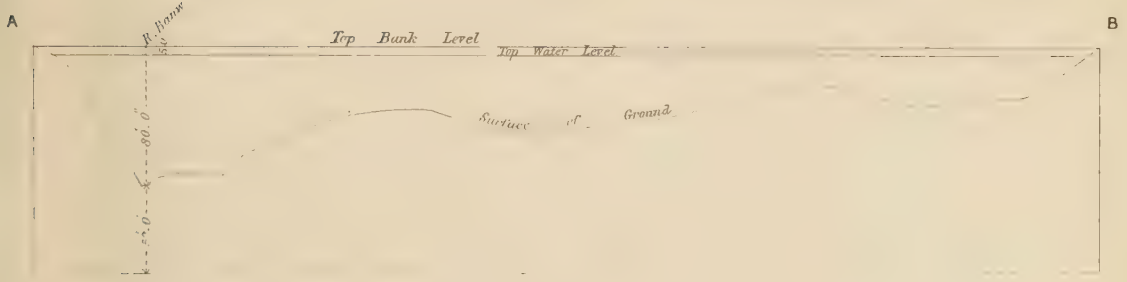
Vertical Scale for Sections



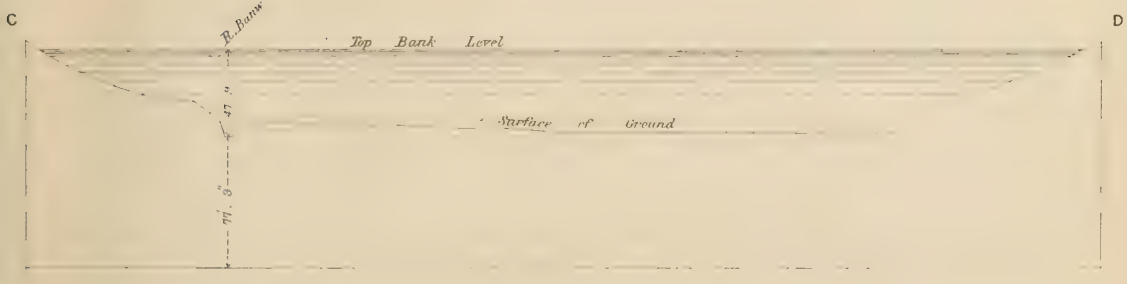
PROPOSED CAN-OFFICE RESERVOIR

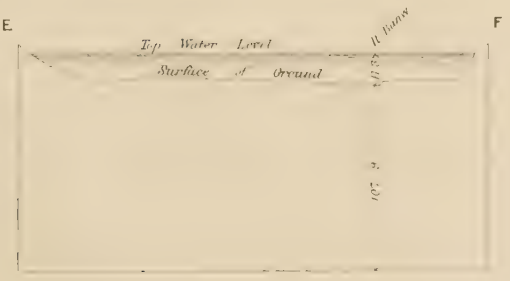
PLAN OF RESERVOIR

LONGITUDINAL SECTION OF EMBANKMENT.



TRANSVERSE SECTIONS OF RESERVOIR





Scale for Plan

furlongs 8 7 6 5 4 3 2 1 0 1 2 miles

Horizontal Scale for Sections

feet 100 0 500 1000 1400 feet

Vertical Scale for Sections

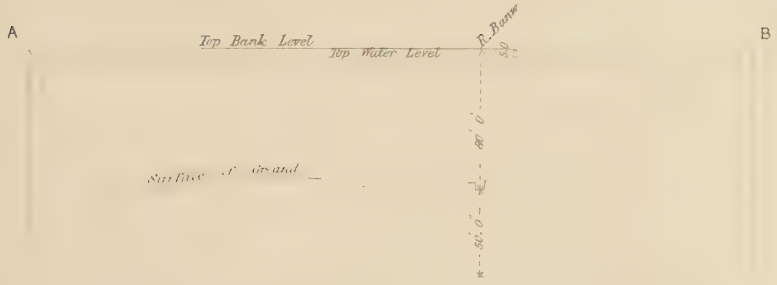
feet 10 0 50 100 150 200 feet

PROPOSED RHYD-Y-GRO RESERVOIR

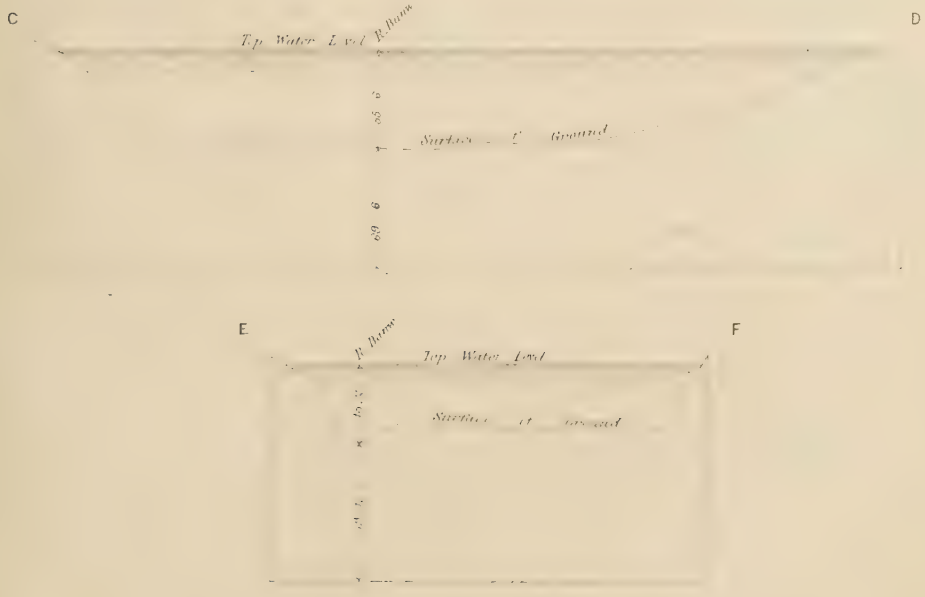
Appendix A (5)

PLAN OF RESERVOIR

LONGITUDINAL SECTION OF EMBANKMENT



TRANSVERSE SECTIONS OF RESERVOIR.



Scale for Plan

furlongs 8 7 6 5 4 3 2 1 0 1

Horizontal Scale for Sections

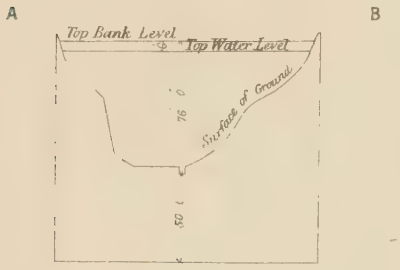
500 1000

Vertical Scale for Sections

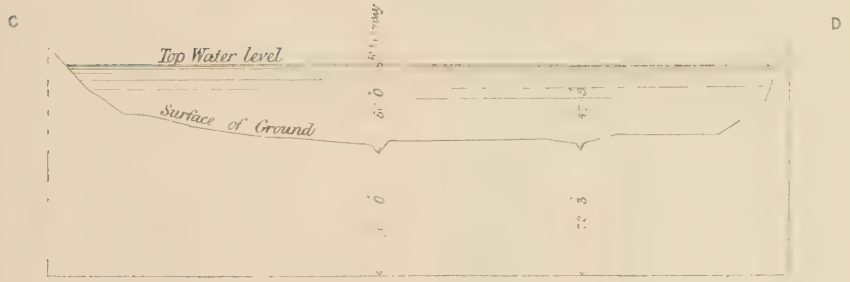
PROPOSED LLANWDDYN RESERVOIR.

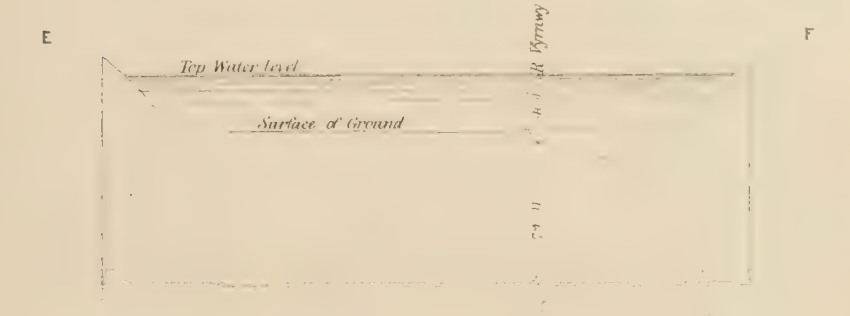
PLAN OF RESERVOIR.

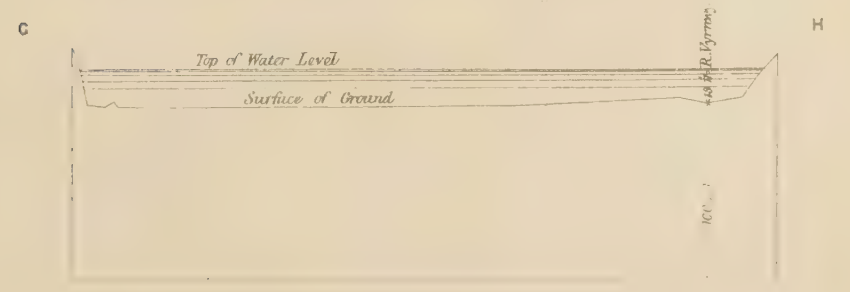
LONGITUDINAL SECTION OF EMBANKMENT.



TRANSVERSE SECTIONS OF RESERVOIR.







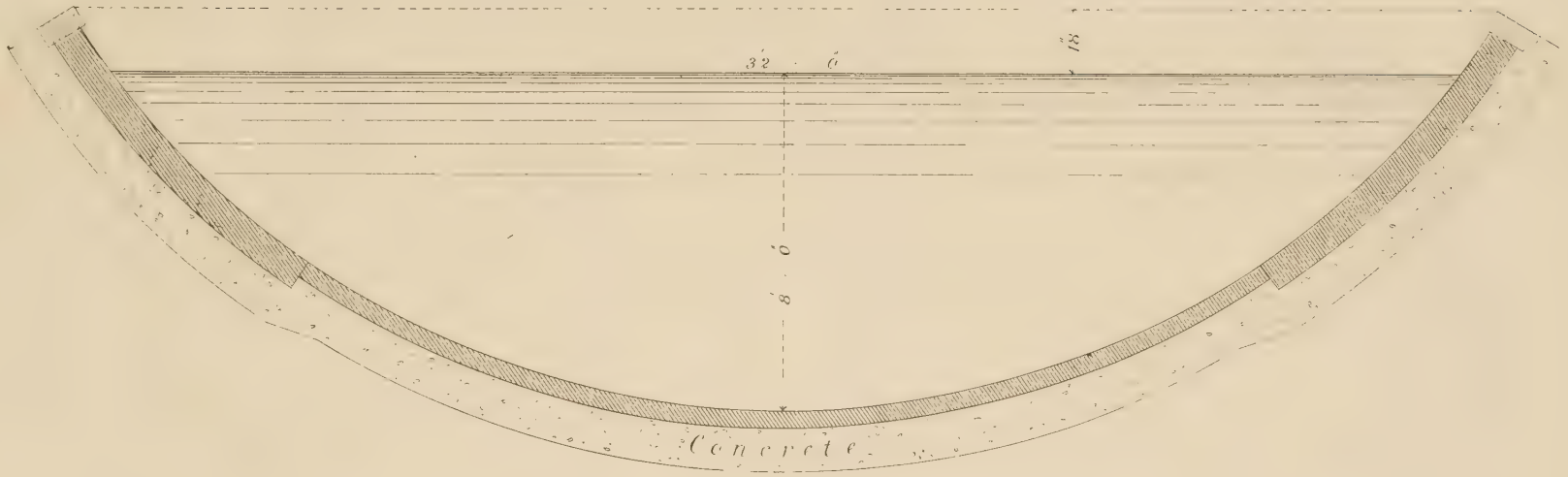
Scale for Plan

Horizontal Scale for Sections

Vertical Scale for Sections

FLOOD WATERCOURSE FROM RIVER VYRNWY AT PONT HAGEL TO RESERVOIR AT RHYD-E-GRO.

(referred to in Appendix M)



Area 177·8 Square feet — Wetted sides 37·1 feet — Fall 15 feet per mile

$$\frac{177\cdot8}{37\cdot1} = \sqrt{4\cdot792\ HMD \times 30\ ft\ fall} = 11\cdot98 \times \frac{10}{11} = \overset{\text{mean vel}^{ty}}{10\cdot9} \quad \overset{\text{Area}}{177\cdot8} \times \overset{\text{Velocity}}{10\cdot9} = 1{,}938\ c\ feet\ per\ sec^{d}\ discharge$$

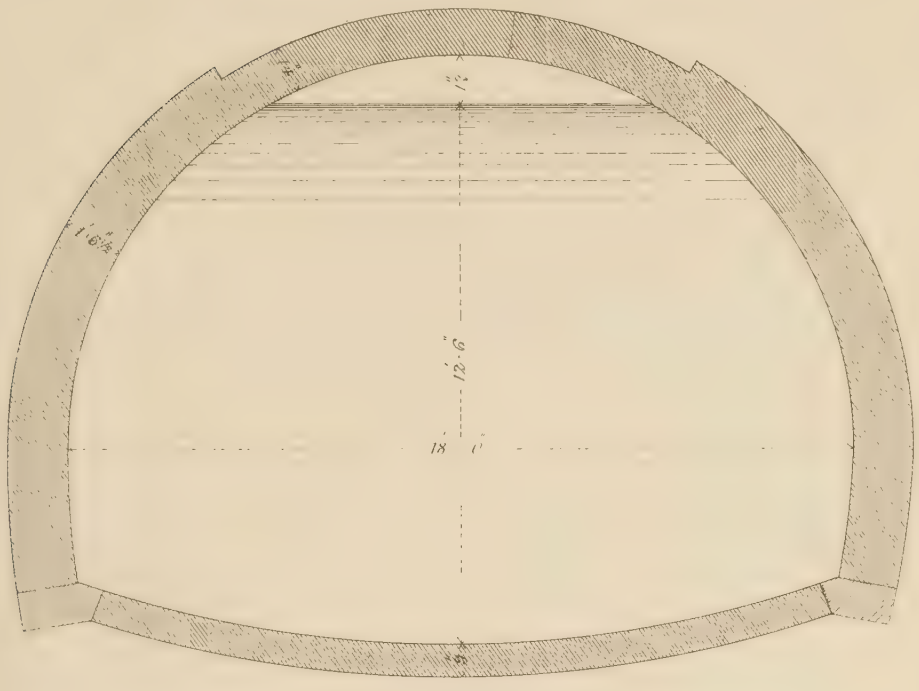
ESTIMATE – PER LINEAL YARD

Brickwork — Welsh blue bricks	2⅓	*cy* @	*40/-*	£ 4 · 13 · 4
Concrete	4¾	*cy* "	*10/-*	2 · 7 · 6
Ashlar Coping	3	*cf* "	*2/-*	0 · 6 · 0
Excavation	30	*cy* "	*2/-*	3 · 0 · 0
				10 · 6 · 10
Sundries, &c, &c.				13 · 2
				£ 11 · 0 · 0

Appendix A.Q. (1).

TUNNEL FOR CONVEYANCE OF FLOOD WATER.

(referred to in Appendix M.)



Area 191.2 sq. ft._Wetted sides 43·6 feet.__Fall 15 ft. per mile.

$\frac{191.2}{43.6} = \sqrt{4.385 \ H.M.D. \times 30} = 11.47 \times \frac{10}{11} = 10.5$ *ft. mean velocity*

$\overset{area}{191.2} \times \overset{velocity}{10.5} = 2011.6$ *cubic feet per second discharge.*

ESTIMATE PER LINEAL YARD.

Brickwork	*7⅓ cy.*	*30/.*	£11 . 0 . 0
Skewbacks	*11 cf.*	*2/.*	1 . 2 . 0
Excavation expected to be shale	*30 cy.*	*6/.*	9 . 0 . 0
			21 . 2 . 0
Sundries			0 . 18 . 0
			£22 . 0 . 0

RANCH AQUEDUCT FROM VYRNWY AND BANW DISTRICT TO MARTEN MERE

Open Watercourse — average Section.

Area 127 Square feet — Wetted sides 29.2 feet — Fall 6 ins: per mile

$$\frac{127}{29.2} = 4.35 \; HMD \sqrt{4.35 \times 1} = 2.08 \times \frac{10}{11}\,ths = \underline{1.9 \text{ feet mean velocity}}$$

$$\text{Area } 127 \times \text{m.v. } 1.9 = 241.3 \text{ c feet per sec.}^{d} \times \text{Gallons in one c}^{ft} \text{ per day } 540,000 = \underline{130\,302\,000 \text{ Gallons per day}}$$

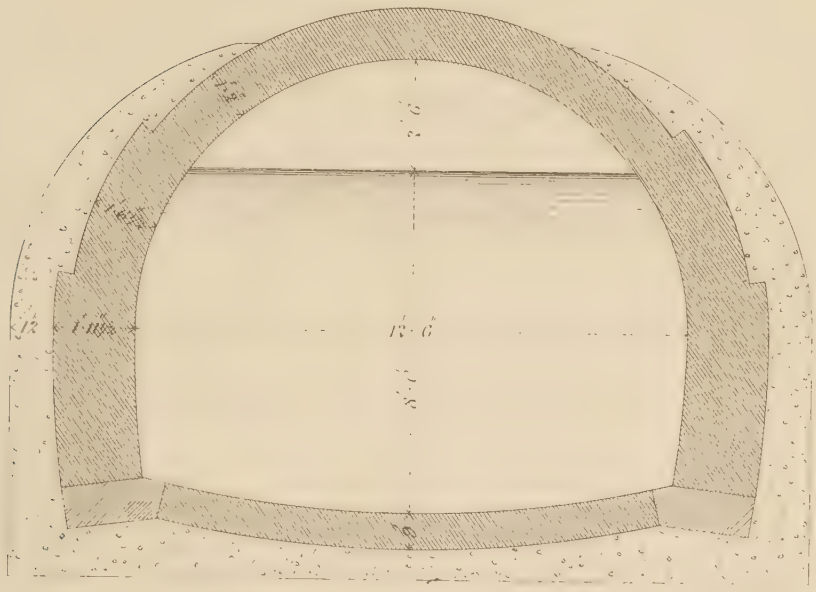
ESTIMATE PER LINEAL YARD.

Brickwork	4 cy @	20/	£ 4 " 0 " 0
Ashlar Coping &c:	12 cf @	2/	1 " 4 " 0
Concrete	2¼ cy "	10/	1 " 2 " 6
Excavation &c:	30 cy "	2/	3 " 0 " 0
			9 " 6 " 6
Sundries			0 " 13 " 6
			£ 10 " 0 " 0

1760 lin[l] yards @ £10 " 0 " 0 = £17,600 per mile
Bridges, Culverts Drains, Fencing &c 2,500
£ 20,100 per mile

RANCH AQUEDUCT FROM VYRNWY AND BANW DISTRICT TO MARTEN MERE

Covered Watercourse or Tunnel_average Section



Area 92.4 s. feet_Wetted sides 27.16 ft.__ Fall 14 ins: per mile.

$\frac{92.4}{27.16} = \sqrt{3.4\ H.M.D} \times 2.33 = 2.82 \times \frac{40}{11} = 2.56$ *mean velocity*

$92.4^{\text{area}} \times 2.56^{\text{m.v.}} = 236.544$ *c/ft. per sec.d* $\times\ 540{,}000 =$ *127,733,760 gallons per day*

ESTIMATE PER LINEAL YARD.

Brickwork	*5⅞ cy*	*20/-*	£ *5 . 16 . 8*
Skewbacks	*13⅛ cf*	*2/-*	*1 . 6 . 4*
Concrete	*5.35 cy*	*10/-*	*2 . 13 . 6*
Excavation &c	*40 cy*	*2/-*	*4 . 0 . 0*
			£ *13 . 16 . 6*
Sundries			*0 . 8 . 6*
			£ *14 5 0*

1760 lin.l yards at £14.5.0 £ *25,080 per mile*
Culverts, Drains &c *1,000*
£ *26,080 per mile*

Say £26,100 per mile

NOTE.. *This Aqueduct will discharge 150,000,000 Gallons per day if required, by a little additional depth of water.*

PARTICULARS AND DETAILED ESTIMATE OF SYPHON PIPES

4 FEET CAST IRON PIPES

Area 12·5664 Square feet Velocity 3·02 feet per second

Discharge ——— 20,282,169 Gallons in 24 hours

Add 25 per cent for difference between Theoretical and Actual Discharge ——— 5,070,542

25,352,711 Gallons in 24 hours

ESTIMATE PER LINEAL YARD

4 feet Pipe 1¼ inch thick equal to a pressure of water of 150 feet in height

Weight per lineal yard: 18 cwt. at 6/- per cwt ——— £5 · 8 · 0

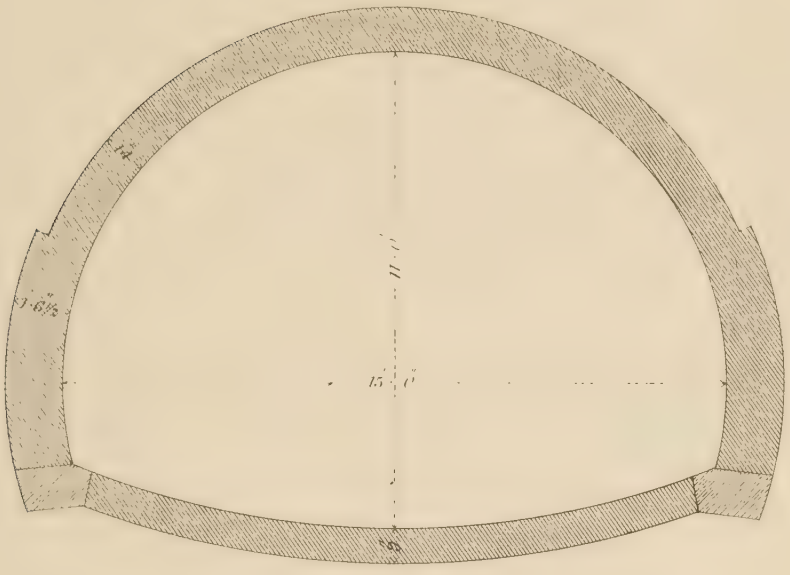
Laying and jointing, including excavating and refilling trench ——— 0 · 15 · 0

£6 · 3 · 0

1760 lineal yards at £6 · 3 · 0 £10,824 per mile for each line of pipes.

TUNNEL FOR CONVEYANCE OF FLOOD WATER FOR RIVER CLWYEDOG TO RIVER CERVST.

(referred to in Appendix M.)



Area=134 square feet.— Wetted sides 41.2. Fall 25 feet per mile.

$\frac{134}{42 \cdot 1} = 3.183$ *H.M.D.* $\sqrt{3.183 \times 50} = 12.6 \times \frac{10}{11} = 11.5$ *feet mean velocity.*

$\overset{\text{area}}{134} \times \overset{\text{velx.}}{11.5} =$ *1,541 c feet per second.*

ESTIMATE PER LINEAL YARD.

Brickwork	*5½ cy.d.*	*30/.*	£ 8 . 5 . 0
Ashlar	*9 c.ft.*	*2/.*	0 . 18 . 0
Excavation &c.	*21 cy.*	*10/.*	10 . 10 . 0
			19 . 13 . 0
Sundries			. 7 . 0
			£ 20 . 0 . 0

BRANCH AQUEDUCT FROM SEVERN DISTRICT TO MARTEN MERE

Open Watercourse_ average Section.

Area 108·755 Square Feet_Wetted sides 26·2 feet_Fall 6 ins: per mile.

$\frac{108\cdot755}{26\cdot2} = 4\cdot15$ H.M.D. $\sqrt{4\cdot15 \times 1} = 2\cdot03 \times \frac{10}{11}^{ths} =$ 1·84 feet mean velocity.

Area Veloc.y
108·755 × 1·84 = 200·21 c feet per Sec.d = 108 113 400 Gallons per day.

ESTIMATE PER LINEAL YARD

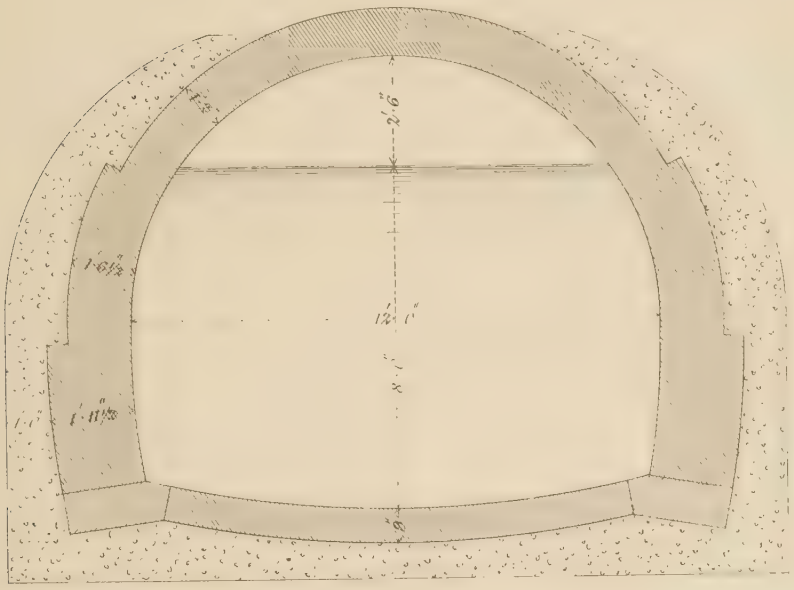
Brickwork	2½ cy	@ 20/-	£ 2 „ 2 „ 3
Ashlar	7½ c.f	„ 2/-	0 „ 15 „ 0
Concrete	2⅓ cy	„ 10/-	1 „ 3 „ 4
Excavation	25 cy	„ 2/-	2 „ 10 „ 0
			6 „ 10 „ 7
Sundries			0 „ 9 „ 5
			£ 7 „ 0 „ 0

1760 lineal yards @ £ 7 = £ 12,320 per mile
Bridges, Culverts Drains & Fencing 2,500 „
£ 14, 820 per mile

Vincent Brooks Day & Son Lith:

BRANCH AQUEDUCT FROM SEVERN DISTRICT TO MARTEN MERE

Covered Watercourse or Tunnel_average Section



Area 87·93 Square feet_Wetted sides 26·5 feet_Fall 12 ins: per mile.

$\frac{87.93}{26.5} = 3.31$ *H.M.D.* $\sqrt{3.31 \times 2} = 2.57 \times \frac{10}{11}$ *ths* $=$ *2·33 feet mean velocity.*

87·93 x 2·33 = 204·88 c feet per Sec^d x 540,000 = 110,635,200 Gallons per day.

ESTIMATE PER LINEAL YARD

Brickwork	*5½ cy @ 20/*	£ 5 " 10 " 0
Ashlar	*13¼ cf . 2/*	1 " 6 " 6
Concrete	*3¾ cy . 10/*	1 " 17 " 6
Excavation &c:	*36 cy . 2/*	3 " 12 " 0
		12 " 6 " 0
Sundries		0 " 1¼ " 0
		£ 13 " 0 " 0

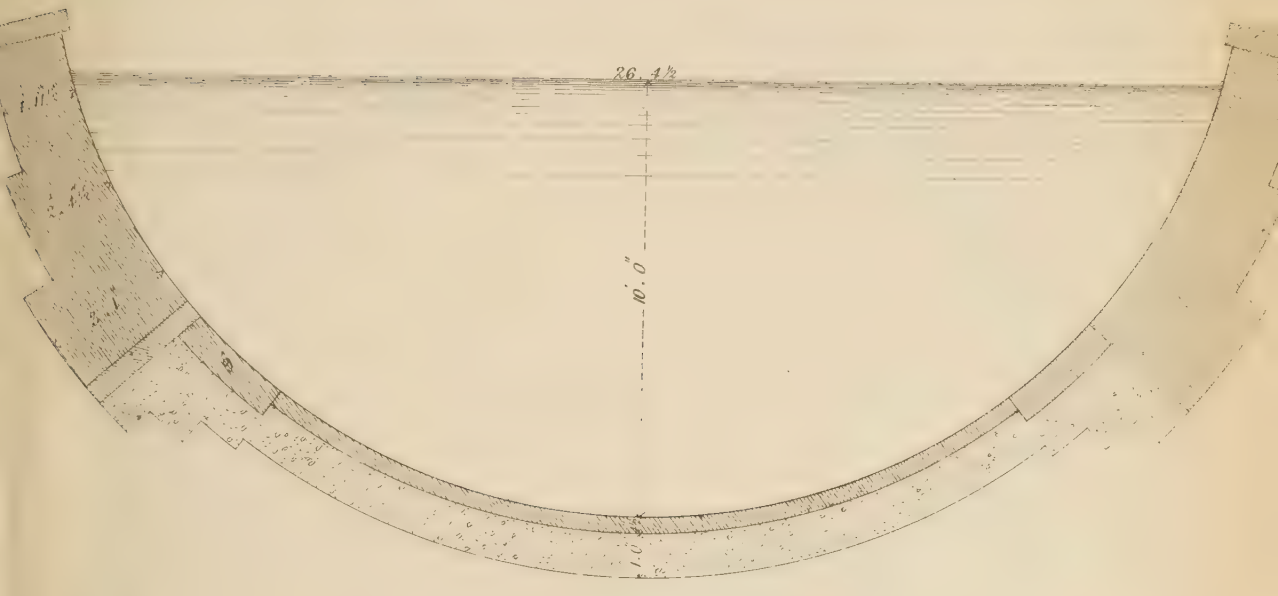
1760 lin^l yards @ £13 ——— *£22,880 per mile*
Culverts Drains &c: ——— *1,000 " "*
£ 23 880 per mile

Say £24,000 per mile.

METROPOLIS WATER SUPPLY.

MAIN AQUEDUCT FROM MARTEN MERE TO SERVICE RESERVOIRS NEAR EDGWARE

Open Watercourse *average Section.*



Area = 193·4 Square feet_ Wetted sides 35 feet_ Fall 6 ins: per mile

$\frac{193\cdot4}{35} = \sqrt{5\cdot526\ H.M.D. \times 1} = 2\cdot357 \times {}^{10}/_{11} =$ *2·143 feet mean velocity*

193·1 Area × 2·143 Velocity = 111·5 cubic feet per sec^d × 540,000 = 72,000,000 Gallons p^r day

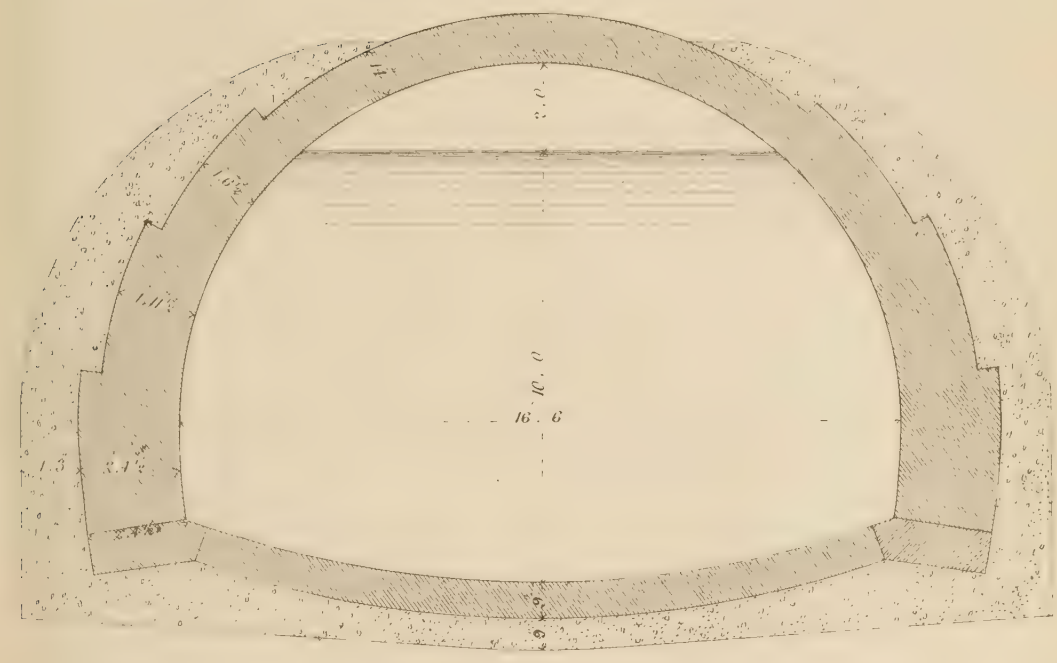
ESTIMATE PER LINEAL YARD.

Brickwork	*5¼ c.y*	*20/*	£ 5 - 5 - 0
Concrete	*4 c.y*	*10/*	2 - 0 - 0
Ashlar Skewbacks	*14¼ c.f*	*2/*	1 - 8 - 6
Excavation	*35 c.y*	*2/*	3 - 10 - 0
			£ 12 - 3 - 6
Sundries			0 - 6 - 6
			£ 12 - 10 - 0

1760 lin^l yards at £12·10·0 = £ 22,000 per mile
Bridges, Culverts Drains fencing &c: 3,000
£ 25,000 per mile

MAIN AQUEDUCT FROM MARTEN MERE TO SERVICE RESERVOIRS NEAR EDGWARE

Covered Watercourse or Tunnel average Section.



Area 116·25 Square feet. Wetted sides 34·866 feet. Fall 14 ins per mile

$\sqrt{\frac{116.25}{34.866}} = 1.195$ H M D $\sqrt{1.195 \times 2.333} = 3.12 \times {}^{10}/_{11} = 2.844$ *mean velocity*

Area. Vely.
$116.25 \times 2.844 = 115.935$ *c feet per Second* $\times$ *540,000* $=$ *224,604,900 Gallons per day*

ESTIMATE PER LINEAL YARD.

Brickwork	*7½ c.y.*	*20/*	£ *7 - 10 - 0*
Ashlar Skewbacks	*15½ c.ft.*	*2/*	*1 - 11 - 0*
Concrete	*7 c.y.*	*10/*	*3 - 10 - 0*
Excavations &c: &c:	*50 c.y.*	*2/*	*5 - 0 - 0*
			17 - 11 - 0
Sundries &c:			*9 - 0*
			£ *18 0 0*

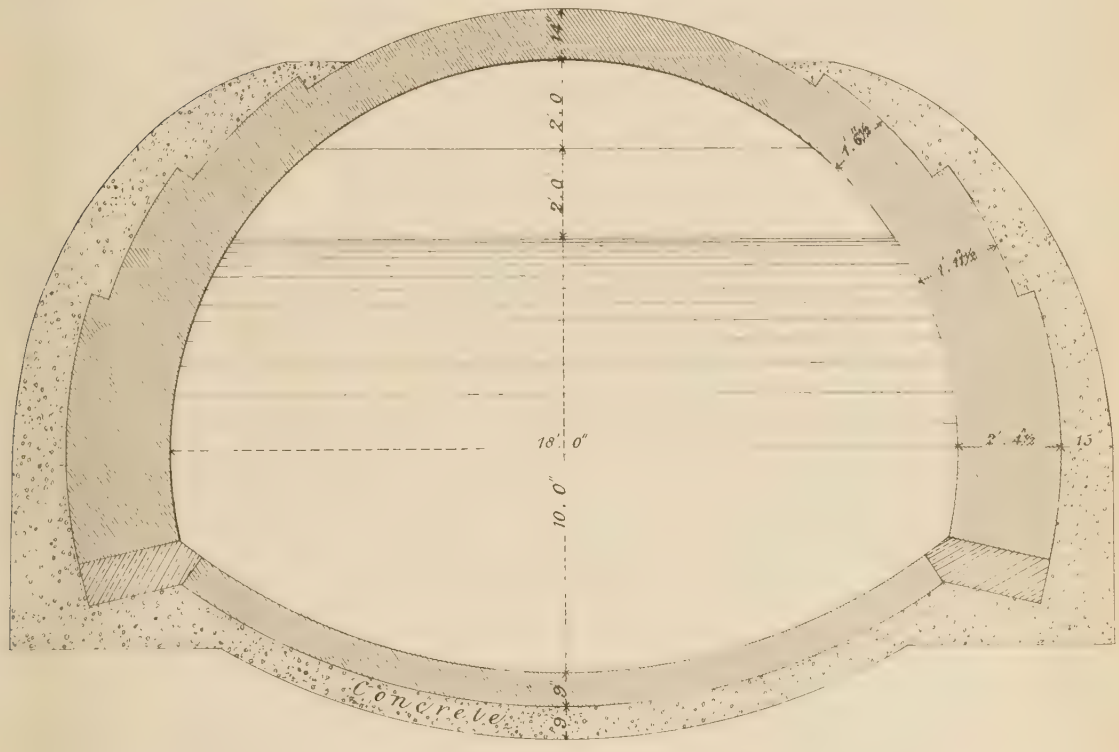
1760 lin^l yards @ £ *18 per lin^l yard* £ *31,680 per mile*
Drains, Culverts &c: &c: *1,500*
£ *33,180 per mile*

Vincent Brooks, Day & Son, Lith.

METROPOLIS WATER SUPPLY.

MAIN AQUEDUCT FROM MARTEN MERE TO EDGWARE IF MADE FOR THE CONVEYANCE OF 300,000,000 GALLONS PER DAY.

Covered Watercourse or Tunnel.



If conveying 230,000,000 Gallons per day_Water 10 feet deep

Area 153 Square feet_Wetted sides 33.5 feet_Fall 11 inches per mile

$\frac{153}{33.5} = \sqrt{1.06\ HMD \times 2.33} = 3.00 \times \frac{10}{11}^{ths} = 2.7$ *mean velocity*

Area. Velocity
153 × 2.7 = 113.1 *cubic feet per second* × 540,000 = *233,071,000 Gallons p^r day*

If conveying 300,000,000 Gallons per day_Water 12 feet deep

Area 180 Square feet_Wetted sides 39 feet_Fall 11 inches per mile

$\frac{180}{39} = \sqrt{1.61\ HMD \times 2.33} = 3.28 \times \frac{10}{11}^{ths} = 2.98$ *mean velocity*

Area. Velocity
180 × 2.98 = 536.1 *cubic feet per second* × 540 000 = *289,656 000 Gallons p^r day*

ESTIMATE PER LINEAL YARD

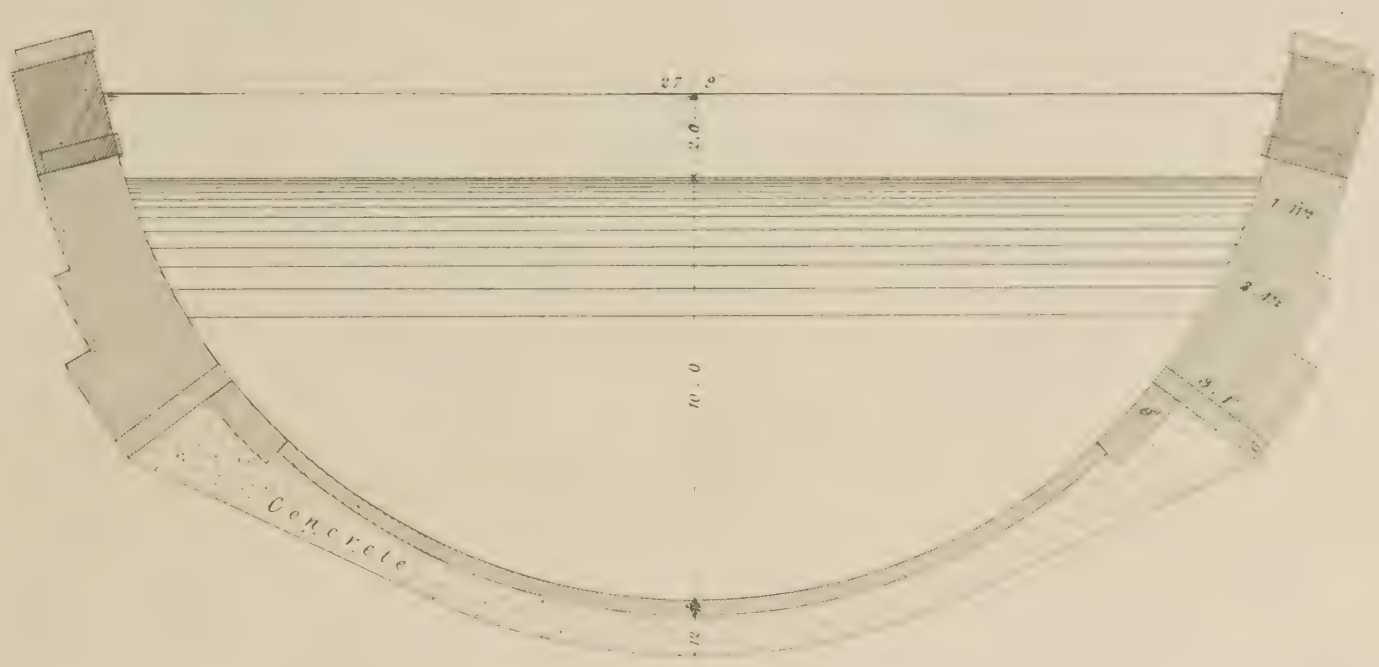
Brickwork	8½	*cy.* 20/	£ 8 - 10 - 0
Ashlar Skewbacks	11	*cf.* 2/	1 - 11 - 0
Concrete	6⅔	*cy* 10/	3 - 6 - 8
Excavation	60	*cy* 2/	6 - 0 - 0
			£ 19 - 10 - 8
Sundries			0 - 9 - 4
			£ 20 - 0 - 0

1760 lin^l yards @ £20 = £35,200 per mile
Bridges Culverts &c: &c: ... 1,600
£36,800 per mile

MAIN AQUEDUCT FROM MARTEN MERE TO EDGWARE

IF MADE FOR THE CONVEYANCE OF 300,000,000 GALLONS PER DAY.

Open Watercourse — average section.



If conveying 230,000,000 Gallons per day_Water 10 feet deep

Area 199 Square feet_Wetted sides 36 feet_Fall 6 inches per mile

$\frac{\overset{\text{Area}}{199}}{36.} = \sqrt{5{\cdot}53\ HMD \times 1/} = 2{\cdot}35 \times {}^{10}/_{11}{}^{ths} = \underline{2{\cdot}13 \text{ mean velocity}}$

$\overset{\text{Area}}{199} \times \overset{\text{Velocity}}{2{\cdot}13} = 423{\cdot}9$ *cubic feet per second* $\times 540{,}000 = \underline{228{,}058{,}200 \text{ Gallons per day}}$

If conveying 300,000,000 Gallons per day_Water 12 feet deep

Area 253 Square feet_Wetted sides 40 feet_Fall 6 inches per mile

$\frac{\overset{\text{Area.}}{253}}{40} = \sqrt{6{\cdot}32\ HMD \times 1/} = 251 \times {}^{10}/_{11}{}^{ths} = \underline{2{\cdot}28 \text{ mean velocity}}$

$\overset{\text{Area}}{253} \times \overset{\text{Velocity.}}{2{\cdot}28} = 576{\cdot}87$ *cubic feet per second* $540{,}000 = \underline{310{,}339{,}920 \text{ Gallons per day}}$

ESTIMATE PER LINEAL YARD

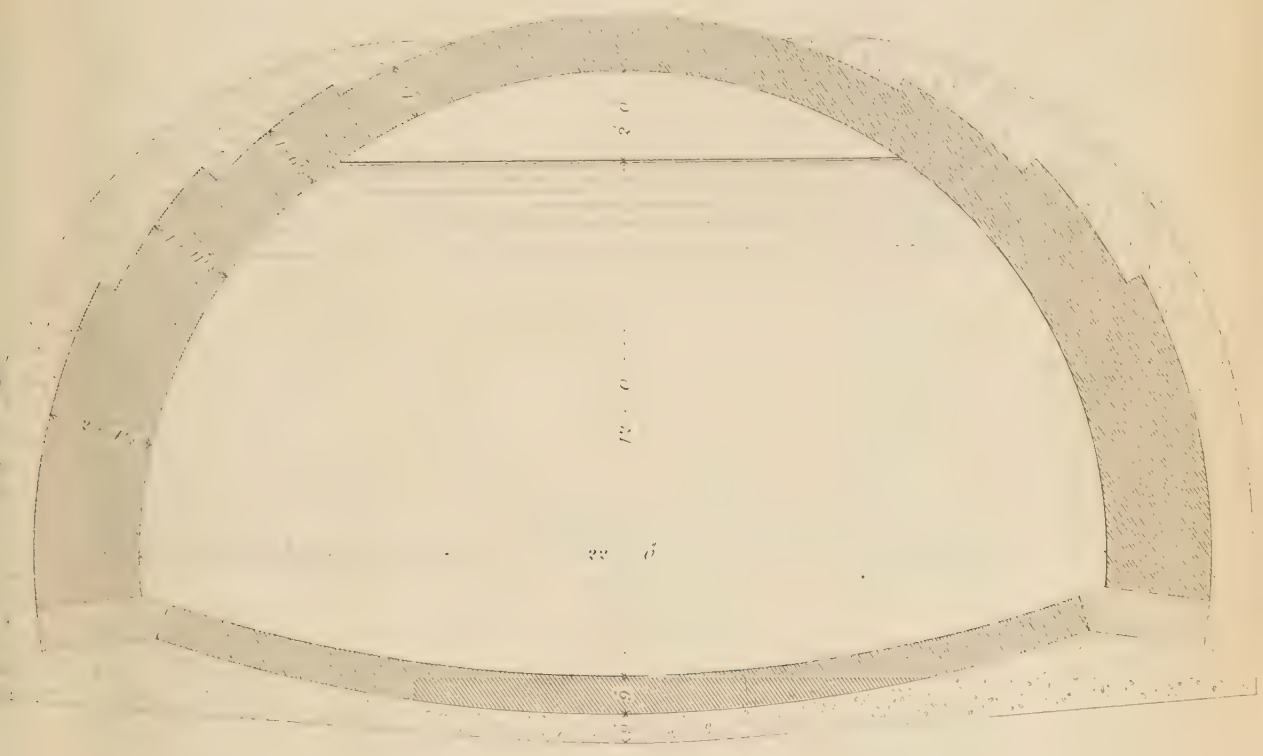
Brickwork	5½ cy @ 20/	£ 5	10 0
Ashlar Skewbacks	11½ cf @ 2/	1	9 0
Concrete	1 cy @ 10/	1	0 0
Excavations &c &c	45 c.y @ 2/	4	10 0
		£ 13	9 0
Sundries			11 0
		£ 14	0 0 per lin[l] yard.

1760 lineal yards @ £14 = £ 24,640
Bridges Culverts Drains Fencing 3,000
£ 27,640 per mile

CUMBERLAND LAKES SCHEME.

AQUEDUCT FROM ULLSWATER TO EDGWARE.

Covered Watercourse or Tunnel — Average Section.



Area 223·3 square feet — Wetted sides 45 feet — Fall 6 ins: per mile.

$\frac{223\cdot3}{45} = 4\cdot96$ H M D $\sqrt{4\cdot96 \times 1} = 2\cdot2 \times \frac{10}{11} =$ 2 feet p^r second mean velocity

$223\cdot3 \times 2 \times 540,000 =$ 241,164,000 Gallons per day.

ESTIMATE.

Brickwork	9⅓ cy	@ 20/-	£ 9 · 13 · 4
Concrete	8 cy	·	4 · 0 · 0
Skewbacks	18 cf	· 2/-	1 · 16 · 0
Excavation, &c, &c,	70 cy	· 2/-	7 · 0 · 0
			22 · 9 · 4
Sundries, &c.			1 · 0 · 8
			23 · 10 · 0

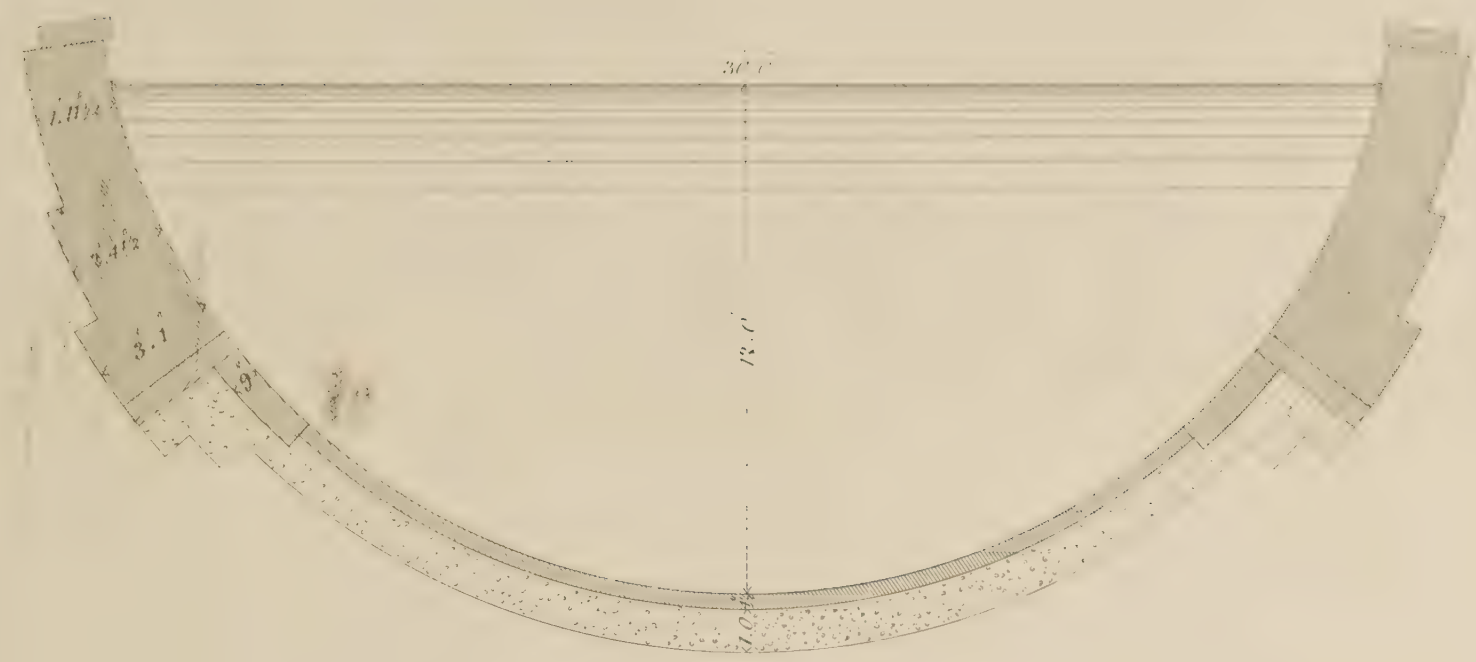
1760 lin^l yards @ £23 · 10 · 0 =	£41,360
Drains, Culverts, &c, &c,	1,500
	42,860
Contingencies 15 per cent	6,429
Land	840
	£50,129 per mile.

say £50,000 per mile.

CUMBERLAND LAKES SCHEME.

AQUEDUCT FROM ULLSWATER TO EDGWARE.

Open Watercourse.—Average Section.



Area = 266 square feet.—Wetted sides 40.8 ft.—Fall 4 ins. per mile.

$\frac{266}{40.8} = \sqrt{6.52 \text{ H.M.D.} \times 0.66} = 2. \times \frac{10}{11} = 1.82$ *mean Velocity.*

$266 \times 1.82 = 484.12$ *cft. per second* $\times 540{,}000 = 261{,}424{,}800$ *gallons per day.*

ESTIMATE PER LINEAL YARD.

Brickwork	5⅔	*cy.*	*20/.*	£ 5	13 4
Concrete	4½	*cy.*	*10/.*	2	5 0
Skewbacks	14½	*cf.*	*2/.*	1	9 0
Excavation	50	*cy.*	*2/.*	5	0 0
				£ 14	7 4
Sundries				0	12 8
				£ 15	0 0

1760 lineal yards at £15 = £26,400 per mile.

Drains, Culverts, Bridges, fencing &c. 3,000

£29,400 per mile

Contingencies 15 per cent. — *4,410*

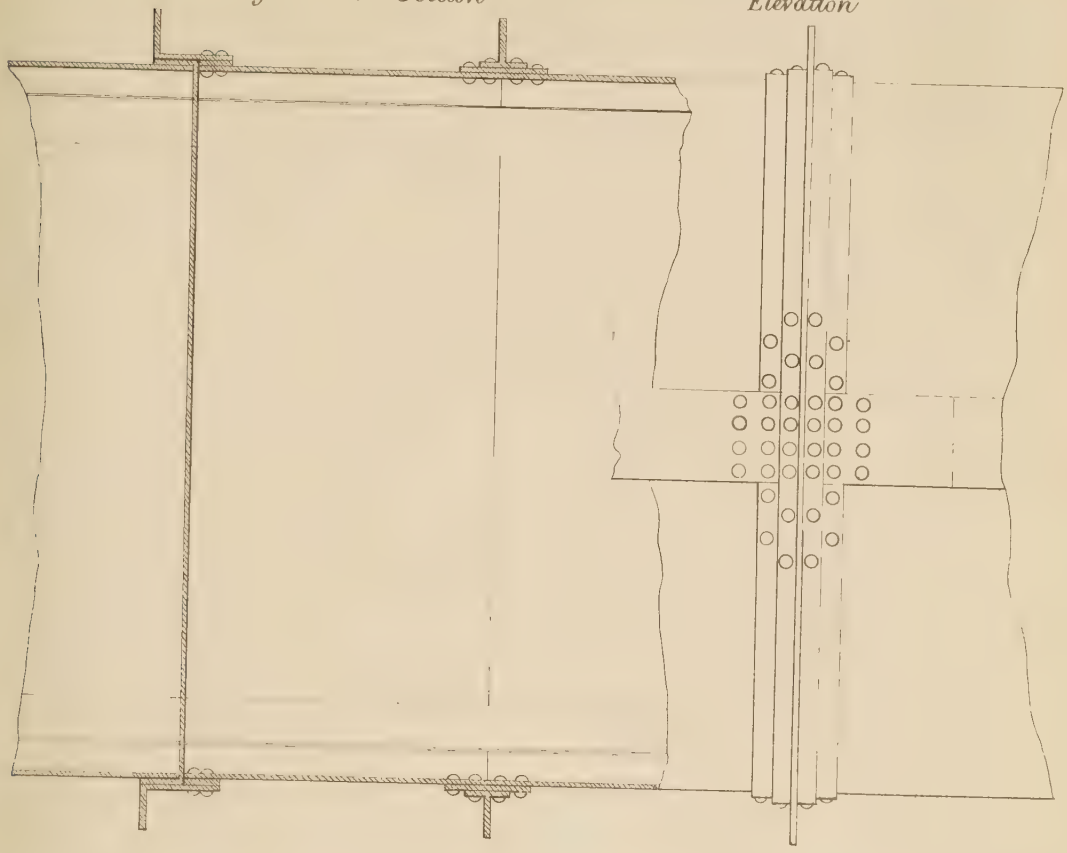
Land — *1,190*

Total £35,000

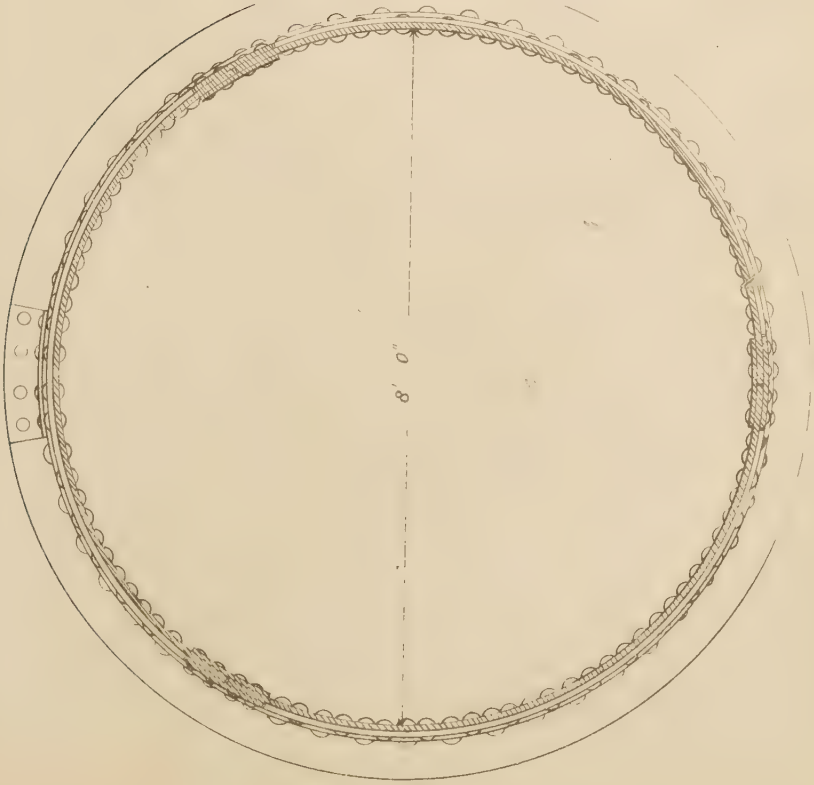
CUMBERLAND LAKES SCHEME.

8 feet Wrought Iron Tubes.

Longitudinal Section *Elevation*



Transverse Section



Scale ½ an inch to One foot

WALES.

HEWING MEAN ANNUAL DEPTH OF RAIN
COMPUTED BY G. J. SYMONS, F.M.S.

MARCH 22ND 1867.

METROPOLIS WATER SUPPLY.

PLAN
SHEWING THE DISTRICTS
SUPPLIED BY THE SEVERAL
WATER COMPANIES.
AND THE POSITIONS OF THEIR
PRINCIPAL WORKS.
1868.

HENDON
HORNSEY
Tottenham High Cross
Stamford Brook
EAST LONDON WATER WORKS RESERVOIR
Crouch End
River Lea
Stamford Hill RESERVOIR AND WORKS
HIGHGATE
PROPOSED RESERVOIR
FILTER BEDS AND WORKS
Leyton Stone
UPPER CLAPTON
STOKE NEWINGTON
HIGHGATE PONDS
RESERVOIR
UPPER HOLLOWAY
HAMPSTEAD PONDS AND WORKS
HAMPSTEAD
RESERVOIR AND WORKS KENTISH TOWN
Cricklewood
River Brent
Willesden
WEST MIDDLESEX
KILBURN
HIGHBURY
NEW RIVER
LOWER CLAPTON
DALSTON
ILFORD
Little Ilford
PRIMROSE HILL RESERVOIR
PORTLAND TOWN
REGENTS PARK
Kensal Green
RESERVOIR
RESERVOIR AND WORKS
STRATFORD
STRATFORD LE BOW
RESERVOIR AND WORKS
WEST HAM
BARKING
River Roding
BETHNAL GREEN
EAST LONDON
BROMLEY
PLAISTOW
EAST HAM
HANWELL
EALING
ACTON
GRAND JUNCTION.
Grand Junction Canal
ST PAULS CATHEDRAL
LIMEHOUSE
HYDE PARK
Buckingham Palace
RESERVOIR AND WORKS
WEST MIDDLESEX
HAMMERSMITH WORKS
RESERVOIR AND WORKS
CHELSEA
RIVER THAMES
ROTHERITHE
ISLE OF DOGS
THAMES
BRENTFORD
KEW
RESERVOIR AND WORKS
RESERVOIRS AND WORKS
Greenwich Observatory
Greenwich Royal Naval College
DEPTFORD
GREENWICH
WOOLWICH
RESERVOIR AND WORKS
PLUMSTEAD
Old Charlton
HOUNSLOW
ISLEWORTH
BARNES
MORTLAKE
FULHAM
BATTERSEA
SOUTHWARK & VAUXHALL
HOLLAND TOWN
CAMBERWELL
PECKHAM
CLAPHAM
RESERVOIR AND WORKS
RESERVOIR
RESERVOIR
Shooter's Hill
East Wickham
East Sheen
PUTNEY
WANDSWORTH
RESERVOIRS
RICHMOND
RESERVOIR
Brixton
Brixton Hill
Balham Hill
RESERVOIRS
DULWICH
LEWISHAM
ELTHAM
KENT.
TWICKENHAM
River Crane
River Wandle
River Ravensbourne
PETERSHAM
HANWORTH
UPPER TOOTING
NORWOOD
STREATHAM
TOOTING
LAMBETH
CRYSTAL PALACE & PARK
Southend
PROPOSED FILTER-BEDS
TEDDINGTON
HAMPTON
Bushey Park
WORKS
RESERVOIR AND WORKS
SUNBURY
KINGSTON
Hogs Mill River
Merton
MITCHAM
BECKENHAM
PROPOSED PUMPING STATION
River Mole
WALTON ON THAMES.
RESERVOIRS AND WORKS
FILTER BEDS AND WORKS
THAMES DITTON
LONG DITTON
CROYDON

SCALE.
8 4 0 1 2 3 Miles

Vincent Brooks Day & Son Lith.

APPENDIX AX. (1.)

Preliminary Report from Drs. Frankland and Odling on the Waters of the Thames Basin.

College of Chemistry,
Oxford Street, July 13, 1868.

Sir,

Herewith we send you the results of our partial analyses of all the samples of water submitted to us by the Royal Commission on Water Supply. From the extended character of the investigation, as well as in some degree from the pressure of other engagements, we regret that we are not as yet able to furnish you with our complete results, but we expect to be able to let you have them very shortly.

Our results so far as they have gone lead to the following conclusions:—

1. The head waters of the Thames closely resemble the waters obtained from chalk springs and borings at Watford, Amwell, and other places in the Thames Basin. They are hard, but free to a remarkable extent from organic matter.

2. The water of the Thames within half a mile below Lechlade does not differ substantially from that of the Thames at Hampton; but the amount of organic matter contained in the water of the river at these two points is about eight times that contained in the head waters.

3. Nowhere between Lechlade and Hampton do we find the water of the Thames more pure than at these two points, while at many intermediate points, notably below Reading, it is much less pure.

4. We have not found the water of any tributary to the Thames below Lechlade, that we have examined, preferable to the water of the Thames at Hampton for the purposes of town supply.

5. Our examination of the series of samples illustrating the purification of the sewage of Croydon by its passage over cultivated land shows the very great advantage which may follow the adoption of this process. But we think it right to observe that the extreme degree of improvement indicated by our results in that particular set of experiments is in considerable excess of the degree of improvement which we have observed on other occasions, although this also is very marked.

Regretting much our inability, at the present moment, to let the Commission have our complete results and report,

We are, &c.,
E. Frankland.
W. Odling.

To William Pole, Esq., F.R.S.

APPENDIX AX. (2.)

Report on the Chemical Quality of Samples of Water collected in the Basin of the Thames. By Dr. E. Frankland, F.R.S., and Dr. Odling, F.R.S.

To the Royal Commission on Water Supply.

My Lord Duke and Gentlemen,

Having been intrusted by you with the chemical analysis of a number of samples of water, collected by Mr. William Pole, F.R.S., from the River Thames and its tributaries, and from artesian wells in the chalk, we have now the honour to submit to you the results of our examination.

The samples were selected apparently with a view to ascertain—

1st. The chemical character of the principal feeders of the Thames, and of the water obtained by artesian borings in the chalk.

2nd. The change in the chemical character of Thames water consequent on its flow through a populous district.

3rd. The extent to which town sewage can be purified by its passage over or through land under the process of irrigation.

The following table contains a list of the samples transmitted to us by Mr. Pole, the dates of their collection, and our remarks on the appearance of the samples when seen in a quart decanter.

Place of collection.	Date of collection.	Appearance of samples.
Syrefords Spring (Lower Oolite)	1868.	
Thames Head Well (Upper Oolite)	March 18th*	Clear and colourless.
Ampney Park Springs (Upper Oolite), and Boxwell Spring (Upper Oolite) mixed	April 18th	Clear and colourless.
Thames at St. John's Bridge, below Lechlade.		
Thames at Midley Lock, above Oxford.	„ 29th	Turbid and yellowish.
River Cherwell, above Oxford.	„ 29th	Turbid and very slightly yellow.
Thames at the Gut below Oxford.	„ 29th	Turbid, greenish yellow.
Thames at the Weir above Abingdon.	„ 30th	Turbid, very slightly yellow.
River Thame, just before junction.	„ 30th	Clear and colourless.
Thames at Caversham Bridge, above Reading.	„ 24th	Turbid, yellowish.
River Kennet, above Hungerford.	„ 20th	Clear and colourless.
River Kennet, just above Reading.	„ 24th	Turbid, slightly greenish yellow.
Thames, just below Reading.	„ 24th	Very turbid, yellow.
Thames at Shiplake, 5 miles below Reading.	„ 25th	Turbid, greenish yellow.
Thames at Medmenham	April 25th	Turbid, yellowish.
Thames, just above Windsor.	May 2nd	Turbid, slightly yellow.
Thames, 2 miles below Windsor sewers outfall.	„ 2nd	Turbid, yellowish.
Thames, above Staines	„ 2nd	Turbid, slightly yellow.
River Wey, above Godalming.	April 21st	Clear, slightly greenish yellow.
Thames at Water Companies intake at Hampton.	May 4th	Very slightly turbid, faint yellow tint.
River Mole	„ 4th	Turbid, yellowish.
River Loddon on Bagshot Sands.	April 21st	Clear, deep brownish yellow.
Mimram and Lee mixed	May 5th	Very turbid, yellowish.
Amwell Well	„ 5th	Clear and colourless.
Otter's Pool Spring, Watford.	April 8th	Clear and colourless.
Artesian Well at Caterham.	May 12th	Clear and colourless.
Artesian Well at Croydon.	„ 11th	Clear and colourless.
Croydon sewage as it flows upon land.	„ 11th	Very turbid and semi-opaque.
Croydon sewage as it flows off land.	„ 11th	Turbid, greenish yellow.
River Wandle, about 3 furlongs below the point where the purified sewage enters.	„ 11th	Very slightly turbid, colourless, many cysts and animalculæ.
River Wandle at Mitcham.	„ 11th	Slightly turbid, colourless, some animalculæ.

* Should be April 18th.—W. Pole.

The analyses were conducted in the manner already described in our report on the samples collected in North Wales and in the Lake District of Cumberland and Westmoreland. The following tables are to be read in the manner there described.

The waters of wells, of springs, and of streams near their sources, were submitted by us to analysis after subsidence but without filtration; since these waters would not necessarily require filtration before being supplied to a community. On the other hand, as the river waters would necessarily have to be filtered before being used for water supply, we considered that our results would, in these cases, be more instructive if obtained from water which we had previously filtered.

We have, &c.,
E. Frankland.
Wm. Odling.

Royal College of Chemistry,
Sept. 30th, 1868.

Results of complete Analysis of Thames and other Waters.

Names of substances found.	Syreford, Boxford, Arnpney, and Thames Head Springs mixed.	Thames at Lechlade.	River Cherwell above Oxford.	River Thame.	Kennet above Hungerford.	Kennet a little above Reading.	Wey above Godalming.	Thames at Hampton.	River Mole.	Stream from Bagshot Sands, near Sandhurst College.	Mimram and Lee mixed.	Amwell Well.	Otter Spring, Watford.	Artesian Well at Caterham.
Total solid residue from 100,000 parts of water evaporated and dried at 100° C.	28·25	28·43	32·95	38·53	25·58	25·62	14·83	27·87	23·51	7·05	25·88	31·88	32·36	31·08
Mineral substances in 100,000 parts of each water:—														
Lime	14·00	12·12	13·08	15·03	11·98	11·00	4·72	11·44	8·92	·68	11·43	14·10	14·50	10·60
Magnesia	1·22	1·00	1·18	·95	·58	·88	·50	·92	·81	·35	·35	·86	·80	2·48
Potash	·27	·34	·70	·77	·27	·19	·33	·53	·37	·37	·64	·46	·26	1·11
Soda	1·04	1·10	2·22	2·39	1·17	1·29	1·09	1·36	1·79	1 08	1·45	1·28	1·22	1·44
Sulphuric Acid	1·26	1·62	3·68	4·28	·54	·78	·90	1·92	1·64	·549	·494	1·68	·747	1·96
Carbonic Acid	11·86	9·97	10·48	11·41	10·37	9·44	3·81	9·23	8·12	·81	9·50	11·35	12·06	10·66
Silica	·54	·37	·52	·95	1·18	1·45	1·23	·64	·77	·92	·71	1·36	1·67	2·59
Chlorine	1·04	1·06	1·56	1·83	·54	1·18	1·42	1·48	1·78	1·36	1·484	1·39	1·26	1·35
Nitrogen as Nitrates and Nitrites	·358	·157	·264	·080	·113	·029	·079	·196	·231	·000	·246	·406	·422	·027
Ammonia	·000	·003	·001	·001	·003	·001	·001	·000	·000	·003	·000	·000	·002	·000
Organic substances in 100,000 parts of each water:—														
Organic Nitrogen	·009	·033	·025	·072	·031	·039	·065	·024	·022	·043	·025	·009	·012	·006
„ Carbon	·014	·133	·265	·397	·195	·228	·538	·260	·166	·909	·125	·076	·026	·020
Hardness in 100,000 parts of each water before boiling	21·9	21·9	22·7	25·6	21·7	19·6	8·3	20·0	16·1	1·5	19·9	22·4	24·7	23·4
Hardness in 100,000 parts of each water after boiling	4·9	5·1	5·1	6·4	3·6	2·4	8·0	4·3	4·4	1·5	2·1	5·9	3·7	9·0

Results of partial Analysis of Thames Water.

Names of substances found.	Sources of samples.									
	Thames at Midley (Isis).	Thames below Oxford.	Thames at Abingdon.	Thames above Reading.	Thames just below Reading.	Thames 5 miles below Reading.	Thames at Medmenham.	Thames above Windsor.	Thames below Windsor.	Thames above Staines.
Total solid residue from 100,000 parts of water evaporated and dried at 100° C.	28·4	31·6	31·6	32·7	28·6	30·0	30·4	31·0	30·4	31·2
Mineral substances in 100,000 parts of each water:—										
Ammonia	·001	·000	·002	·001	·001	·001	·000	·002	·003	·000
Nitrogen as nitrates and nitrites	·218	·277	·245	·286	·148	·215	·229	·205	·211	·215
Organic substances in 100,000 parts of each water:—										
Organic nitrogen	·028	·028	·026	·032	·049	·032	·036	·028	·029	·027
Organic carbon	·199	·216	·234	·291	·300	·263	·245	·259	·289	·304
Hardness in 100,000 parts of each water:—										
Before boiling	18·2	19·1	22·0	21·0	18·2	20·0	19·4	22·2	22·4	20·8
Hardness after boiling	7·7	8·2	9·0	8·2	5·7	7·5	7·5	7·4	7·4	10·5

Series of Analyses illustrating Purification of Sewage at Croydon.

Name of substances found.	Sources of sample.				
	Water supply of Croydon.	Croydon sewage as it flows upon land at Beddington.	Croydon sewage as it flows off the land and into the Wandle.	River Wandle 3 furlongs below the point where the sewage enters.	River Wandle at Mitcham.
Total solid residue from 100,000 parts evaporated and dried at 100° C.	32·0	43·6	34·4	30·0	31·0
Mineral substances in 100,000 parts of each sample:—					
Ammonia	·061	2·191	·002	·000	·000
Nitrogen as nitrates and nitrites	·551	·000	·317	·414	·403
Organic substances in 100,000 parts of each sample:—					
Organic nitrogen	·007	1·156	·037	·031	·024
„ carbon	·040	2·798	·099	·100	·099
Total combined nitrogen	·559	2·960	·356	·445	·427
Hardness in 100,000 parts before boiling	22·0	23·4	23·4	21·7	21·1
Hardness after boiling	9·1	9·7	12·0	8·5	9·7

Additional Observations by Dr. Frankland.

The above analytical results suggest the following observations in connexion with the three objects of the inquiry already mentioned, viz.:—1st. The chemical character of the principal feeders of the Thames, and of the water obtained by artesian borings in the chalk; 2nd. The change in the chemical character of Thames water during its flow through a populous district; and 3rd, the extent to which town sewage can be purified by its passage over or through land in the process of irrigation.

I. *Chemical Character of the principal Feeders of the Thames, and of the Water obtained by Artesian Borings in the Chalk.*

The mixed samples of the five chief head springs in the oolite forming the source of the Thames present a water pleasant to the eye and to the palate. Although this water has drained through cultivated and pasture land, its passage through the oolite has almost completely deprived it of the organic matter with which it was at first doubtless contaminated; the same remark applies also to all the samples of water from chalk springs and wells, as seen from the following table:—

	Organic carbon in 100,000 parts of water.	Organic nitrogen in 100,000 parts of water.
Head Springs of Thames -	·014	·009
Amwell Well - - -	·076	·009
Otter's Pool Spring, Watford -	·026	·012
Artesian Well at Caterham -	·020	·006
„ „ Croydon -	·040	·007
„ „ Deptford* -	·053	·006
„ „ Bromley† -	·033	·008

It is worthy of remark that, although the amount of organic matter in these waters is very small, it is highly nitrogenized.

With the sole exception of the Caterham water, all the samples exhibit a high previous sewage contamination, as seen from the following table:—

	Previous sewage contamination in 100,000 parts.
Head Springs of Thames - - -	3,260
Amwell Well - - -	3,740
Otter's Spring, Watford - - -	3,920
Artesian Well at Caterham - -	0
„ „ Croydon - -	5,200
„ „ Deptford - -	3,540
„ „ Bromley - -	3,670

Although the previous sewage contamination of all the above waters, with one exception, is greater than that of Thames water, yet it has much less significance, on account of the excessive amount of filtration which these waters have received in the oolite or chalk, and which may be presumed, with considerable probability, to have removed the noxious germs of organisms present in the excrementitious matters with which the waters had been in contact. The danger, therefore, attending the domestic use of water once contaminated with sewage or manure matter is here reduced to a minimum, and, with stringent precautions against the admixture of surface water, may, perhaps, be regarded as almost a vanishing quantity.

The great objection to these waters is their excessive hardness, which exceeds that of Thames and Lea water by about 6°. It is true that they may be softened to about one-fifth of their natural hardness by the application of Clark's process; but there appears to be no hope of this somewhat delicate chemical operation being carried out successfully upon such a vast volume of water as that supplied daily to the metropolis, when it is seen that the very simple mechanical process of filtration through sand is not efficiently performed in the case of the present water supply. After trying Clark's process for some time at Plumstead, the engineer to the Kent Water Company states that he was compelled to abandon it as utterly impracticable. The plan is still used at Caterham and Tring, but upon a scale far too small to permit of any safe conclusion being drawn as to its applicability to the entire supply of the metropolis.

Notwithstanding the small proportion of actual organic matter in the chalk waters of the London basin, they are still for domestic purposes much inferior to the Welsh and Cumberland samples, as is seen from the following comparison:—

* May 20th, 1868.
† Feb. 18th, 1868.

	Total solid impurity.	Organic carbon.	Organic nitrogen.	Previous sewage contamination.	Hardness.
Head Springs of Thames -	28·25	·014	·009	3,260	21·9
Amwell Well - - -	31·88	·076	·009	3,740	22·4
Otter Spring (Watford) -	32·36	·026	·012	3,920	24·7
Artesian Well at Caterham -	31·08	·020	·006	0	23·4
„ „ Croydon -	32·00	·040	·007	5,200	22·0
„ „ Deptford -	41·20	·053	·006	3,540	27·1
„ „ Bromley -	31·20	·033	·008	3,670	20·5
Bala Lake - - - -	2·79	·227	·001	0	·4
Ullswater Lake - - -	3·63	·067	·000	0	1·9
Thirlmere Lake - - -	2·66	·194	·004	0	·7
Haweswater Lake - -	3·56	·158	·004	0	1·3

The principal feeders of the Thames which we have examined, exclusive of the head waters, are, on the other hand, without exception, ill adapted, if not utterly unfit, for domestic purposes. They are all decidedly inferior to the Thames itself at Hampton. Near their source, the Kennet, the Wey, and the stream from Bagshot sands are clear, and the first-named stream is also colourless; but, with the exception of the Thame, they are all, where they join the Thames, turbid, and when viewed in a quart decanter, exhibit a yellowish, greenish-yellow, or brownish yellow colour. With the single exception of the stream from Bagshot sands, they all contain a large amount of highly nitrogenized organic matter, indicating sewage or manure pollution which has not been destroyed by oxidation. The small proportion of organic nitrogen to carbon in the stream from Bagshot sands shows the organic matter to be of vegetable origin, indeed the deep brownish yellow colour of this water proves that it contains peaty matter, and in such quantities as to render it unfit to be used as a beverage.

With the exception of the last-named stream, and the Kennet, just above Reading, all these affluents of the Thames exhibit a considerable previous sewage contamination, a charge against them which is not mitigated by excessive filtration, as in the case of the chalk and oolite waters already alluded to.

The hardness of these waters is greater than that of Thames water as delivered in London, with the exception of the water of the Mole, which is somewhat softer, that of the Wey above Godalming, and that of the stream from Bagshot sands, which are much softer, the last being in this respect fully equal to the average of the samples from Wales and Cumberland, which we have already reported upon.

It will be seen from the following comparison of the analytical results yielded by these feeders of the Thames with the mean of those given by Thames water as delivered in May last, by the five companies supplying the metropolis from that river, that not one of these affluents could be substituted with advantage for any portion of the present metropolitan supply. The River Mole alone exhibits in some respects slight advantages over Thames water; but these are more than counterbalanced by the notorious turbidity of this river, and the great difficulty of rendering its waters clear by filtration.

	Total solid impurity.	Organic carbon.	Organic nitrogen.	Proportion of organic nitrogen to organic carbon, N : C =	Previous sewage contamination.	Hardness.
Thames water as delivered in London, May 8th 1868*	26·40	·184	·023	1 : 8·0	1,275	18·6
River Cherwell - -	32·95	·265	·025	1 : 10·6	2,330	22·7
River Thame - -	38·53	·397	·072	1 : 5·5	490	25·6
River Kennet, above Hungerford	25·58	·195	·031	1 : 6·3	830	21·7
„ „ just above Reading	25·62	·228	·039	1 : 5·8	0	19·6
Stream from Bagshot Sands	7·05	·909	·043	1 : 21·1	0	1·5
Wey above Godalming -	14·83	·538	·065	1 : 8·3	480	8·3
River Mole - - -	23·51	·166	·022	1 : ·5	1,990	16·1

* Weekly return of Registrar General, No. 22, 1868.

II. *The Change in the Chemical Character of Thames Water during its flow through a populous District.*

The alterations in the chemical character of Thames water during its flow from the oolitic head springs to Hampton are shown in the following table, in which the samples are arranged in the order of the places whence they were taken, from the sources of the river downwards. I have also added the average of the results obtained in the analysis of the waters supplied to London on the 8th of May last by the West Middlesex, Grand Junction, and Southwark Com-

panies, who abstract water from the Thames at Hampton, and by the Chelsea and Lambeth Companies, who draw from the Thames below the junction of the Mole. These additional results are extracted from my Report to the Registrar General, contained in his weekly return, No. 22, 1868.

Places where samples were taken.	Total solid impurity in 100,000 parts.	Organic carbon.	Organic nitrogen.	Proportion of organic nitrogen to organic carbon.	Nitrogen as nitrates and nitrites.	Ammonia.	Total combined nitrogen.	Previous sewage contamination.	Hardness before boiling.	Hardness after boiling.	Date of collection of sample.	Distance of place of collection from sources of Thames.	Population on banks of river and tributaries between places of collection. (Census 1861.)*
Head Springs of Thames	28·25	·014	·009	1 : 1·6	·358	·000	·367	3260	21·9	4·9	March 18th	Miles.	
Thames at St. John's Bridge, below Lechlade	28·43	·133	·033	1 : 4·0	·157	·003	·192	1270	21·9	5·1	April 18th	21½	58,015
Thames at Midley Lock (Isis)	28·4	·199	·028	1 : 7·0	·218	·001	·247	1870	18·2	7·7	„ 29th	46½	70,050
„ the Gut, below Oxford	31·6	·216	·028	1 : 7·7	·277	·000	·305	2450	19·1	8·2	„ 29th	49½	95,469
„ the Weir, above Abingdon	31·6	·234	·026	1 : 9·0	·245	·002	·273	2150	22·0	9·0	„ 30th	56	3,676
„ above Reading	32·7	·291	·032	1 : 9·1	·286	·001	·319	2550	21·0	8·2	„ 24th	86	128,223
„ just below Reading	28·6	·300	·049	1 : 6·1	·148	·001	·198	1170	18·2	5·7	„ 24th	87½	100,912
„ at Shiplake, five miles below Reading	30·0	·263	·032	1 : 8·2	·215	·001	·248	1840	20·0	7·5	„ 25th	91½	1,681
„ Medmenham	30 4	·245	·036	1 : 6·8	·229	·000	·265	1970	19·4	7·5	„ 25th	100	89,082
„ just above Windsor	31·0	·259	·028	1 : 9·6	·205	·002	·235	1750	23·2	7·4	May 2nd	117¼	43,082
„ two miles below Windsor sewers	30·4	·289	·029	1 : 10·0	·211	·003	·243	1820	22·4	7·4	„ 2nd	122	20,091
„ above Staines	31·2	·304	·027	1 : 11·2	·215	·000	·242	1830	20·8	10·5	„ 2nd	125	4,864
„ at Hampton	27·87	·260	·024	1 : 10·8	·196	·000	·220	1640	20·0	4·3	„ 4th	137½	219,103
„ Water from Hampton delivered in London	26·27	·183	·025	1 : 7·3	·159	·001	·185	1280	18·4		„ 8th	153	0
„ Water from below junction with Mole, delivered in London	26·60	·186	·021	1 : 8·9	·158	·001	·180	1270	19·0		„ 8th	153	48,081
													882,329

* I have much pleasure in acknowledging the valuable assistance of the Secretary to the Rivers Commission, S. J. Smith, Esq., in the laborious compilation of this population table.

It is obvious, from an inspection of the foregoing table, that such a series of analyses, although otherwise highly instructive, can only very imperfectly illustrate the chemical changes which *a given volume of water* undergoes, during its flow from its source to Hampton. In the first place, the number of samples of tributaries examined, though considerable, is far too small to enable us to judge of the total effect, upon the main body of the stream, which is produced by its affluents. Thus, of the head waters of the river which, meeting at or near Lechlade, form the main stream of the Thames, the springs constituting the sources of the Thames proper, the Churn, and the Coln, only were examined; whilst the waters of the Swillbrook, the Leach, the Ray, and the Cole, were left unexplored, although the two last are very considerable streams. Again, of the great number of tributaries below Lechlade, only seven were examined, and even in these cases, where the quality of the affluent was ascertained, its relative quantity was not determined. It is also well known that the Thames is fed by numerous powerful springs, which rise in the bed of the stream at various points of its course.*

Secondly, the samples could not possibly be collected at the times when the same body of water was passing the different points where they were obtained; in fact, the same body of water flowing in a river does not pass consecutively any series of points on the banks; because the superior water strata flow more rapidly than the inferior, and the centre of the stream than the lateral portions, consequently, even if a float had been placed in the stream, and each sample taken at the moment when the float passed the place of collection, the consecutive samples would still have been very far from representing one and the same volume of water moving down the bed of the river. It is indeed evident that the Thames, in its flow from its source to Hampton, is constantly undergoing changes, now tending to purification, now to pollution; here it receives a tributary purer than itself, there one more polluted; at one place it is pent up by a weir, and flows sluggishly over a thick stratum of putrescent mud; then it dashes down the weir and flows as a rippling stream over a clean pebbly bed, becoming aerated to the maximum; now it receives the sewage of a town, and then it is reinvigorated by a gush of spring water in its bed; and these complicated changes are not merely affecting successive individual volumes of water as they flow on, but these volumes immediately afterwards lose their individuality, owing to the varying velocity of flow in different parts of the same river section. No series of analyses, therefore, however great the number of samples, or care bestowed on their collection, could, in the case of such a river as the Thames, illustrate exactly the changes produced in a stream by any one of the numerous causes of change above enumerated—the effect of the population residing on the banks, for instance.

Nevertheless, the above series of analyses demonstrates conclusively certain points of the highest importance, as regards the use, present and prospective, of the Thames, or its tributaries, for the supply of the metropolis with water.

* See the evidence of the Rev. J. C. Clutterbuck, in the Report of the Select Committee on the Thames River, 1865, page 53.

The head waters of the Thames which we have examined, containing but a very small proportion of organic impurity, become by the time they reach Lechlade, as impure, in this respect, as the Thames at Hampton; the organic carbon is increased nearly tenfold, and the organic nitrogen nearly fourfold. On the other hand, the previous sewage contamination, which, as indicated by analysis, is always to be regarded as the minimum, has decreased from 3,260 to 1,270; this may be due to the comparative freedom from such contamination of the important feeders of the Thames above Lechlade which have not been submitted to analysis; or it may arise from the action of aquatic vegetation upon the head waters during their average flow of 21 miles to Lechlade; the latter is certainly one of the causes, and it is probably the more important of the two. It nearly ceases in winter.

Judging from the samples taken, the Thames at Hampton contains less solid impurity and organic nitrogen than at any other point of its course; the organic matter is also less highly nitrogenized here than at any point higher up the stream, except at the foot of the Weir above Staines, where, however, the difference in favour of the latter point is very slight; the proportion of nitrogen to carbon being 1 : 11·2 at Staines, and 1 : 10·8 at Hampton. After leaving its sources, therefore, the water of the Thames is purer and better adapted for domestic purposes at Hampton than at any other point in its course. This highly remarkable circumstance, coupled with the fact that between Staines and Hampton, a distance of only 12½ miles, the Thames water suffers a diminution of 3·33 parts of solid impurity, ·044 part of organic carbon, and ·003 part of organic nitrogen in 100,000 parts of water, indicates some powerful cause of amelioration between these points. A reference to the ordnance map shows that two very important tributaries, the Colne and the Wey, enter the river between the points at which the Staines and Hampton samples were taken. No sample was collected from the River Colne, and the analysis of the sample of the Wey above Godalming only partially accounts for the amelioration; since although it contained 16·37 parts of solid impurity per 100,000 less than the Thames at Staines, it yielded ·234 part more organic carbon, and ·038 part more organic nitrogen. It is to be remarked, however, that the Wey sample was collected on April 21st, when Mr. Pole says, "river somewhat in flood and rather turbid," whilst the Staines and Hampton samples were taken on the 2nd and 4th of May respectively. It is to be regretted that samples of these affluents were not taken near their junction with the Thames, on the same day that the Staines and Hampton samples were collected. With the evidence now available, it is impossible to do more than conjecture the cause of the remarkable amelioration of the Thames between Staines and Hampton.

With a view to ascertain the effect of the towns of Oxford, Reading, and Windsor, upon the quality of the river water, three samples were taken in each case, viz., one immediately above the town, another at a point below the town where the drainage becomes mixed with the water, and a third at a point some miles below, but before the river receives any further affluent, or is influenced by any other important riparian source of alteration; the object of this latter sample

being to ascertain what change was produced on the quality by the flow. At Oxford and Reading, where a tributary entered through the town, it was also necessary to take a sample of the tributary above the town.

At Oxford the effect of the sewage upon the filtered waters of the Thames and Cherwell is not very striking; it is, in fact, to some extent concealed by the material difference in composition of the Thames and Cherwell as they enter Oxford, and by the circumstance, that the relative volumes of these streams are unknown. The Cherwell is, in nearly every respect, more impure than the Thames, as might be expected from its having been contaminated by the sewage of Banbury (pop. 11,000) and other places. The united waters, after receiving the pollutions of Oxford, contain, in 100,000 parts, only ·015 more combined nitrogen than the Cherwell; but if we assume the volume of the Cherwell to be one-fourth that of the Isis, then the following table shows the composition of the mixed waters before and after admixture with the Oxford sewage.

——	Before admixture.	After admixture.	Addition to impurity by admixture.
Total solid impurity -	29·3	31·6	2·3
Organic carbon - -	·212	·216	·004
„ nitrogen -	·027	·028	·001
Total combined nitrogen -	·256	·305	·049
Previous sewage contamination.	1962	2450	488
Hardness - - -	19·1	19·1	0

The rate of flow of the combined streams of the Isis and Cherwell below Oxford is unknown, but assuming it to be 200,000,000 of gallons in 24 hours, the addition to the total combined nitrogen in the filtered river water ought to be about ·041. The above table gives it ·049 in 100,000 parts.

The change produced in the quality of the water by the flow of the river down to the lock above Abingdon (about seven miles), ought to be shown by a comparison of the sample taken below Oxford with that collected just above Abingdon, but unfortunately the latter sample was not taken on the same day as the former, and therefore the results of the two analyses are not comparable quantities; indeed, the increase in hardness of no less than 2·9 degrees at Abingdon shows that from some cause, independent of the mere flow of the stream, the character of the water had materially altered during the time which elapsed between the taking of the two samples. The water at the lock above Abingdon contained, after filtration, exactly the same amount of solid impurity as that below Oxford. It also contained ·018 part per 100,000 more organic carbon, ·002 part less organic nitrogen, ·002 part more ammonia, ·032 part of combined nitrogen, and 300 parts of previous sewage contamination less than the water below Oxford.

At Reading, a similar series of samples was taken, but here, as at Oxford, a large tributary, of unknown proportional volume and of very different chemical character, enters the Thames, and complicates the result. Reading is only partially sewered, but from the evidence given before the Rivers Pollution Commission, a large amount of sewage finds its way into the Kennet, and night-carts are also emptied into the stream. Mr. Pole states that the samples around Reading were collected after a few days of showery weather, the Kennet "near its junction with the Thames "running, at a rough estimate, about 200 millions of gal-"lons per day." The volume of the stream could, therefore, not be much smaller than that of the Thames itself. Assuming it to be two-thirds that of the Thames just above the junction, the following table exhibits the composition of the united filtered waters before and after admixture with the Reading sewage:—

——	Before admixture.	After admixture.	Addition to impurity by admixture.
Total solid impurity -	29·87	28·6	0
Organic carbon - -	·266	·300	·034
„ nitrogen -	·035	·049	·014
Total combined nitrogen	·219	·198	0
Previous sewage contamination - -	1520	1170	0
Hardness - -	20·4	18·2	0

These results show that in passing Reading the waters of the Thames and Kennet receive a well-marked accession to the organic matter which they previously contained; but the analytical numbers also indicate that the waters of the two streams had not become uniformly mingled at the point where the sample of the mixed waters was taken, which was only a quarter of a mile below the junction of the two streams. If we assume that at the point where the sample was taken the waters were mixed inversely as the proportions above given, then the accession of "total solid impurity," "total combined nitrogen," and "previous sewage contamination," in the above table, would receive positive values.

The last sample of the Reading series was taken at Shiplake Mill, about five miles below Reading, on the day following that on which the other samples of the series were collected; no safe conclusions can therefore be drawn from the results of its analysis, regarding the effect of the flow of five miles upon the quality of the water contaminated with the Reading sewage. A comparison of the impurities in the filtered water, taken just below the town, with those in the filtered sample collected at Shiplake Mill, shows an increase of 1·4 part of total solid impurity in 100,000 parts of water, of 670 parts of previous sewage contamination, and of 1·8 of hardness; whilst it shows a decrease of ·037 part of organic carbon, and ·017 part of organic nitrogen.

The last series of samples was taken at Windsor, viz., one about half a mile above the bridge; a second at the ferry at Old Windsor, nearly two miles below the sewer outfall; and a third at the foot of the weir above Staines, just before the junction of the Colne. As no considerable tributary enters the Thames between the points at which these samples were collected, and as they were also all taken on the same day, the chief disturbing causes which affected the two other series were here absent. The following table exhibits a comparison of the analytical results yielded by the three filtered samples:—

——	Above Windsor.	Two miles below sewer outfall.	Increase of impurity after admixture with sewage.	Five miles below sewer outfall.	Decrease of impurity after flow of three miles.
Total solid impurity in 100,000 parts	31·0	30·4	0	31·2	0
Organic carbon - -	·259	·289	·030	·304	0
„ nitrogen -	·028	·029	·001	·027	·002
Total combined nitrogen - - -	·235	·243	·008	·242	·001
Previous sewage contamination - -	1750	1820	70	1830	0
Hardness - -	22·2	22·4	·2	20·8	1·6

An inspection of this table would indicate that the sewage of Windsor produces practically no effect upon filtered Thames water, and further that a flow of three miles effects substantially no alteration in the proportion of the several impurities; but it would be hazardous to draw either of these conclusions from this single series of analyses. The towns of Eton, Clewer, Windsor, and Datchet contain, according to the census returns of 1861, a population of 18,198. Supposing the whole of this population to drain into the Thames, and the volume of the river as it flows past Windsor to be 500,000,000 gallons daily, the proportion of organic nitrogen in solution contributed to the stream would amount to only ·002 part in 100,000 parts of water, the above analyses show ·001, the increase of previous sewage contamination ought to be 100, analysis shows 70, and the theoretical increase of total combined nitrogen is ·010, whilst the accession actually found amounts to ·008. These numbers are, however, so small that they might well be regarded as falling within the limits of experimental error; they certainly cannot be taken as a basis for the solution of either of the questions proposed.

The effect of flow upon the nitrogenous organic matters dissolved in Thames water can be more certainly investigated, by taking as a basis, the contamination produced upon the 100,000,000 gallons of water flowing, according to Mr. Pole's estimate, past Lechlade, by the 58,015 persons residing on the banks of the tributaries above that point. This contamination, as shown by analysis, amounts to ·133 part organic carbon and ·033 part organic nitrogen in 100,000 parts of water. Taking this as the relation between riparian population and river contamination, it follows that the 834,248 persons residing on the banks of the Thames and its tributaries above Hampton ought to communicate to 800,000,000 gallons of water, the average daily flow of the river past Hampton, a contamination equal to ·239 part of organic carbon and ·059 part of organic nitrogen in 100,000 parts of water.

The amounts actually found at Hampton by analysis were ·260 part of organic carbon and ·024 part of organic nitrogen in 100,000 parts of water, thus showing an excess of ·021 part of organic carbon and a deficiency of ·035 part of organic nitrogen, the first ascribable to the accession of

peaty and other similar vegetable matters, and the last to oxidation or precipitation of a portion of sewage matter during the flow of the river from Lechlade to Hampton. By calculation from the average amount of soluble organic nitrogen in sewage, the drainage of 834,248 persons into the Thames ought to communicate to the river at Hampton ·062 part of organic nitrogen in 100,000 parts of water—a number which nearly agrees with that (·059) deduced above from, first, the analysis of Thames water just below Lechlade, and, second, the population above the point at which the sample analysed was taken.

III. *The Extent to which Town Sewage can be purified by its Passage over or through Land in the Process of Irrigation.*

Towards the solution of this problem the series of analyses given at page 3 were made. This series illustrates the composition of the water supplied to Croydon, the change which it undergoes in being converted into sewage, the composition of this sewage after it has been used for irrigation, the composition of the River Wandle after admixture with the purified sewage, and, lastly, the composition of the same river after a further flow of one mile. The following table shows the alteration in the composition of the Croydon water in its passage through the successive stages just mentioned. All the numbers refer to 100,000 parts of the water or sewage:—

	Excess of impurity after conversion into sewage.	Excess of impurity after irrigation.	Excess of impurity after mixture with the Wandle.	Excess of impurity after flow of one mile in the Wandle.
Total solid impurity.	11·6	2·4	0	0
Organic carbon -	2·758	·059	·060	·059
„ nitrogen -	1·149	·030	·024	·017
Ammonia -	2·190	·001	·000	·000
Total combined nitrogen.	2·401	0	0	0
Hardness -	1·4	1·4	0	0

An inspection of this table and the one at page 3 shows that the Croydon sewage is very weak. According to Hofmann, Witt, and Way, average London sewage contains of combined nitrogen about 10 parts in 100,000, consequently the Croydon sewage is scarcely one-third of the strength of average London sewage; in fact it is known that the Croydon sewage becomes mixed with a large volume of subsoil water before it reaches the irrigated land at Beddington; nevertheless the great amount of purification effected by this application of the sewage to the land is highly remarkable, and if supported by repeated analyses would prove that for the conversion of the sewage of towns into water as pure as that usually met with in rivers flowing through cultivated land, nothing more is necessary than to apply it to a surface of land of about 10 acres to each 2,000 of the population contributing the sewage.

Unfortunately, however, the amount of purification exhibited by the above series of analyses must be regarded as exceptional, for, although all experiments hitherto made show that sewage may be ameliorated by being employed for irrigation to an extent which cannot be approached by any practical chemical means hitherto devised, yet no analytical determinations, with which I am acquainted, exhibit a degree of purification at all so great as that observed in the results just given. The effluent water from the Beddington meadows at Croydon has been repeatedly examined both by Dr. Odling and myself in summer and winter, but the amount of purification observed previously to the above, by either of us, still leaves the following excess of impurity in the effluent water compared with that present in the water supplied to Croydon:—

	Excess of impurity after irrigation.		
	Maximum.	Minimum.	Mean.
Total solid impurity - -	5·40	2·10	3·75
Organic carbon - - -	·716	·627	·671
„ nitrogen - -	·199	·185	·192
Total combined nitrogen -	·361	0	·218

The above numbers all relate to 100,000 parts of water.

Conclusions.

The conclusions arrived at from the foregoing investigation of the waters of the Thames basin may be thus summarised:—

1. The head waters of the Thames and the waters from chalk wells and springs in the Thames valley contain but a very small proportion of organic matter, which is, however, highly nitrogenised. They are very hard, and, with one exception (the Caterham well water), exhibit a high previous sewage contamination. Although markedly superior to the river waters at present supplied for domestic purposes to the metropolis, they are much inferior to the Welsh and Cumberland samples.

2. All the feeders of the Thames (exclusive of the head waters) which have been examined, are, without exception, ill adapted if not utterly unfit for domestic purposes. They are all decidedly inferior to the Thames itself at Hampton, and consequently none of them could be substituted with advantage for any portion of the present metropolitan supply.

3. The head waters of the Thames are polluted by sewage or manure matters soon after leaving their sources, and on reaching Lechlade are contaminated even to a greater extent than the Thames water delivered in London.

4. The precise effect of the flow of a stream, in purifying the water from sewage or manure matters, cannot be clearly ascertained from the foregoing investigation; but the analytical results demonstrate that at no part of its course does the Thames become freed from the soluble animal organic matters with which it is contaminated, although the total amount of these matters becomes diminished as the stream pursues its course.

5. After leaving its head springs, the water of the Thames is purer and better adapted for domestic purposes at Hampton than at any other point in its course.

6. Irrigation, properly carried out, purifies sewage to a great extent, but not sufficiently to render it admissible into potable water without danger; the risk arising not only from the considerable amount of animal organic matters which the effluent water still retains in solution, but also from the absence of any guarantee for the removal of the germs or other noxious suspended matters which are frequently present in sewage.

E. Frankland.

Note by Dr. Odling.

It may assist the Commission, in interpreting the results of our analyses, to have their attention drawn to the following points:—

1. That unoxidized nitrogen, or nitrogen in the forms of organic substance and ammonia, is the characteristic constituent of animal excretions; and that if the entire daily excretions of the 800,000 persons living above the Thames at Hampton were added at once to 800,000,000 gallons of water, or the daily quantity of water flowing past Hampton (*i.e.*, if the excretions of one average person were added to 1,000 gallons of water), they would give to the filtered water a proportion of unoxidized nitrogen amounting to ·3 part in 100,000 parts.

2. That whereas, in fresh animal excretions almost the whole of the nitrogen exists in the form of organic substance, and but a minute proportion in the form of ammonia, in ordinary town sewage about four-fifths of the dissolved nitrogen has become changed into ammonia, only one-fifth remaining in the form of organic substance; so that if the sewage of 800,000 persons were included at once in 800,000,000 gallons of water, it would give to the filtered water a proportion of nitrogen in the form of ammonia amounting to ·24 part, and a proportion of nitrogen in the form of organic substance amounting to ·06 part in 100,000 parts.

3. That, according to the tables of results, the excess of unoxidized nitrogen in Thames water at Hampton, above that in the Head Springs water, is ·015 part, and the entire amount of unoxidised nitrogen in the water at Hampton, but ·024 part in 100,000, the two waters being alike free from ammonia; whilst, of feeders, &c., of the Thames draining sparsely populated districts, the quantity of unoxidised nitrogen amounts in the Kennet above Hungerford, to ·034 part, including ·003 of ammonia; in the Thames below Lechlade, to ·056 part, including ·003 of ammonia; in the stream from Bagshot sands, to ·046 part, including ·003 of ammonia; in the Wey above Godalming, to ·066 part, including ·001 of ammonia; and in the Thame, to ·073 part, including ·001 of ammonia, in 100,000 parts of water.

William Odling.

APPENDIX AY.

Dr. Pole's Report on the Collection of Further Samples of Water from the Thames Basin.

Committee Room F., House of Lords,
Dear Sirs, Westminster, S.W., Oct. 29, 1868.

In compliance with the desire expressed in Dr. Frankland's letter to me of the 8th inst., and which was assented to by his Grace the Duke of Richmond on behalf of the Commission, I have collected and forwarded to Dr. Frankland the four additional samples of water mentioned by him.

They were all taken, in the same manner as the former samples, on the 28th of October. There had been moderate rain some days before, but three fine days had intervened before the collection, and, as far as I could learn from persons in the neighbourhood, all the rivers were in their usual average condition, both as to quantity and quality.

The following is a list of the samples forwarded:—

From the Thames, just below Staines Weir and above the junction of the Colne (11·20 a.m.):—

Four gallons. Bottles Nos. 36 and 51.
Temperature 8½° Cent.

From the main stream of the Colne, about 200 yards above its junction with the Thames (noon):—

Four gallons. Bottles Nos. 60 and 83.
Temperature 8°.

From the Wey, about 200 yards below the entrance into it of the Basingstoke Canal, and about half a mile above its junction with the Thames (2·45 p.m.):—

Four gallons. Bottles Nos. 35 and 67.
Temperature 8½°.

From the Thames, just above the intake of the Water Companies at Hampton (3·45 p.m.):—

Four gallons. Bottles Nos. 34 and 96.
Temperature 9°.

I am, dear Sirs, yours faithfully,
Wm. Pole.

To Dr. Frankland, F.R.S., and Dr. Odling, F.R.S.

APPENDIX BB.

Report on Gravitation Water Supplies to Large Towns.

To the Chairmen of the London Water Companies.

Gentlemen,

Having been instructed by you to investigate the general question of gravitation supplies of water to large towns, I visited Manchester, Liverpool, Glasgow, Newcastle, and other places, and procured information which has enabled me to arrive at the results given in the following report.

Manchester.

The present population of Manchester is about 470,000, and the quantity of water supplied is about 15 millions of gallons per day, or nearly 32 gallons per head per day for all purposes.

The yield of the spring water in the upper valley of the river Etherow, which forms the gathering ground for the water supply, is stated to be 16 cubic feet per second, or 8½ millions of gallons per day; the balance of 6½ millions being supplied out of the storage reservoirs.

The compensation water to the mills is now 55 cubic feet per second for 12 hours per day, or nearly 15 millions of gallons per day; thus making the present demand upon the works equal to about 30 millions of gallons per day.

To supply this quantity from the drainage ground of 18,900 acres will require 25½ inches rainfall to run off the ground and be stored.

The average rainfall of the last 14 years, over the water-shed, has been about 46 inches. From similar districts the available *minimum* quantity has fallen to less than half the average rainfall; it would therefore seem that until the extra storage reservoirs, now in course of construction, are finished, the safe limit of this gravitation supply—that is, the *available minimum*—has been nearly reached.

From information gathered on the spot, I ascertained that fears were entertained of the water running short in 1865. It appears, however, that the two largest store reservoirs, viz., Woodhead and Torside, have practically never been filled within 15 to 20 feet of their full height; in the case of Woodhead, because it was thought unsafe to fill it owing to a landslip, and to the unsoundness of the embankment; and in the case of Torside, because as a matter of prudence it was thought desirable to keep down the full head, and only increase the level year by year a foot or two; besides which the filling to high-water mark would have drowned out the Crowden Bleach Works, situated near the head of this reservoir. These bleach works have been purchased and are now in course of removal.

Since the year 1865, two new compensation reservoirs have been in course of construction in the valley below Rhodes Wood reservoir, called the Valehouse and Bottom's reservoirs, which are intended to hold 750 million gallons, or 50 days' supply of compensation water; and on their completion it is intended to empty the Woodhead reservoir, and construct a new embankment and other works, to admit of its being filled with safety.

These several additional stores of water will increase the capacity of the works and enable them to supply all demands for probably some years to come; but, at the same time, they are evidence of the weakness of the supply in times of *extreme drought*.

Since the works were constructed, the compensation water given out of the reservoirs to mills and works has been decreased from 75 to 55 cubic feet per second for 12 hours per working day, thus affording an increase of 5,400,000 gallons of water per day for the use of the town. I understand this water has been acquired by purchase from the mill owners, and serves as an additional indication of the weakness of the supply; and but for this relief from the original impost, the works would probably have failed to provide a full supply of water in 1865.

Manchester is most favourably situated for a gravitation waterworks; the abundance of rainfall, and the proximity of high lands with rapid water-sheds, render it a favourable example of a *gravitation* supply, yet there can be little doubt that the spread of population will absorb the increased quantity from the works now constructing, and then the occurrence of three or four dry years in succession will again test its powers of endurance, and new supplies will have to be sought for in more distant localities.

Liverpool.

The present population is about 620,000, and the quantity of water supplied is about 17 million gallons per day, or 27½ gallons per head per day for all purposes. Of this quantity about 7½ millions per day are obtained from wells sunk into the red sandstone, and the remainder, or 9½ millions, from the Rivington Gravitation Works.

The compensation water stipulated to be given to the mills from the Rivington works is 8,300,000 gallons per day, and after deducting this quantity, the total yield of these works in the best years has never exceeded 17 millions of gallons per day; while the maximum quantity supplied to Liverpool in any year has not much exceeded 11 millions of gallons per day, owing to the water run to waste from time to time for want of sufficient storage. Moreover, the quantity of water supplied on the average of the last 11 years has only been a trifle in excess of 9,000,000 gallons per day, while in the years 1864, 1865, and 1866, the average was under 8,000,000, and in 1865 alone only 6,177,000 gallons per day.

The late Mr. Robert Stephenson, in his report of 1850, after fully investigating this subject, stated "that an uniform "supply of 12 or 13 million gallons per day may, in my "judgment, be reckoned upon with absolute certainty."

The average rainfall of the district was originally taken at 48 inches, of which 36 inches was assumed to be available, and one-third of this, or 12 inches, was allowed for mill compensations, leaving 24 inches for Liverpool.

The actual rainfall for an average of 17 years has been 45·70 inches only; the average of 11 years' rainfall delivered to Liverpool has been only 14½ inches, and in 1865 only 9¾ inches, instead of the 24 inches depth originally anticipcted.

The reservoir capacity, compared with the area of the gathering ground, is 50,000 cubic feet per acre, which is a very large amount, notwithstanding which a new store reservoir is in course of construction, 80 acres in area, and intended to hold 1,200 millions of gallons of water. With this additional capacity the entire storage will amount to 68,500 cubic feet per acre, which in a run of dry years has little chance of being filled; indeed, the corporation engineer estimates that even with this increase the average yield will only be equal to 10½ million gallons per day, while reliance should not, he says, be placed on more than 9 million gallons per day in cycles of three dry years.

It thus appears that the ultimate value of this gravitation supply is practically reached, for even if the new store reservoir above alluded to had been originally constructed, and the mean yield of the first five years, viz., about 12½ million gallons per day abstracted, it has been calculated by the engineer that in 1866 the whole of the supply would have been exhausted.

The pumping works for getting water from the red sandstone have been increased during the last two years so as to supplement the Rivington supplies, but this source is limited, as the water in the sandstone basin is gradually lowering, and it is evident that some larger and more comprehensive water supply must before long be brought to bear on Liverpool.

The corporation engineer has reported on various schemes for obtaining supplies more or less distant, and has recommended the Bala Lake scheme in Wales, distant from Liverpool about 45 miles in a direct line.

The Rivington Works are practically a failure as gravitation works; three dry years in succession reduce the available water to 6 millions of gallons per day, and four successive years of drought, which may very probably occur in future, would reduce it still further; and unless enormous reservoirs or lakes could be made, capable of storing the surplus waters of three or four years, these works must prove insufficient.

Penrith.

The particulars of the Penrith water supply (though not gravitation works) serve to show the excessive fluctuation in the quantities of water flowing from the Lake districts.

The town is supplied with water pumped out of the river Eamont, which is the only outlet from Ulleswater Lake. The works are about a mile distant from the town, and all the water required for it was in the first instance raised by the water power of the river; but in the year 1862 the river ran so low that there was scarcely enough water left to turn the wheel, and temporary steam power had to be resorted to to raise the water for the town. Since that year a permanent steam engine of 14-horse power has been fixed for use in short water seasons.

There is a flour mill near the waterworks wheel, which by arrangement has a right to half the water power.

From data obtained I find that in 1862 the quantity of water flowing from Ulleswater, with its gathering ground of about 54,500 acres, was reduced to 20 million gallons per day for some months.

The flow down the river on the 26th ultimo was 120 millions of gallons per day, being about the average flow; showing that in dry seasons the water is reduced to one-sixth the ordinary volume.

Glasgow.

The population of Glasgow is now estimated at about 500,000. The average quantity of water supplied during 1867 was 26½ million gallons per day, or about 50 gallons per head per day for all purposes. Of this water 22½ millions of gallons was supplied from Loch Katrine, and 3¾ millions from the Gorbals Gravitation Works.

Loch Katrine can be drawn upon to the extent of 7 feet of its depth, in which it contains a store of 650 millions of cubic feet, and the drainage ground to the lake being 23,300 acres, there are 28,000 cubic feet of storage capacity per acre.

The scheme was projected by Mr. Bateman as capable of supplying 50 millions of gallons per day to Glasgow.

The tunnels and works near the lake have been constructed of sufficient size to convey this quantity, but a 4-feet aqueduct pipe only has been laid through the valleys towards Glasgow for conveying 20 million gallons of water per day, the original intention being, as I am informed, to have another such pipe, and one of 3 feet, which would altogether convey the 50 million gallons.

Instead, however, of now laying down the second 4-feet pipe, the corporation are laying the 3-feet pipe, which will only increase the present quantity brought to Glasgow by 10 millions—that is to a total of 30 millions of gallons per day. At the same time they are now constructing pumping works on the river Clyde, some distance above Glasgow, to supply 7½ millions of gallons per day for manufacturing purposes.

I was informed by the corporation engineer that the reason for constructing these pumping works is as follows:—There has been for many years a weir across the Clyde, nearly opposite the eastern end of Glasgow Green and originally above the town, but, by the spread of population eastward, it is now nearly in the centre of that part of the river bordered by buildings. The weir was constructed by the old Glasgow Waterworks Company to form a reservoir of water to pump from during the low water of the tide. The manufactories on the river at present draw from this pond, but, on account of the quantity of sewage now flowing into the river, the commissioners are about to remove the weir higher up, and so let the tide at Glasgow ebb fully out. This will deprive the manufactories of their present pumping reservoir, and therefore the corporation are making the works in question to supply them with water.

Considering that one foot additional diameter to the new pipe now being laid from Loch Katrine (viz. increasing it from 3 to 4 feet) would convey an additional 10 million gallons per day, the construction of the pumping works seems to indicate a mistrust in the Loch Katrine supplies during dry years, as it would certainly be cheaper to increase the size of the main and bring in 10 million gallons of water by gravitation than erect pumping works to supply inferior water, in less quantity, at continual cost.

That the Loch Katrine Works can supply 50 million gallons of water to Glasgow in years of extreme drought seems very doubtful. In Mr. Bateman's report of 1853, he states, upon this subject, "Observations upon the volume "of the river Teith flowing over Deanston Mill dam have "been kept for many years. The driest year and the year "in which the longest drought occurred during the period "of the observations, was the year 1826. In that year there "was no rain from the middle of April to the beginning of "August, and the water of the river was insufficient to "drive the machinery at full work, from 6th of May to the "15th August, a period of 100 days."

The quantity of water measured during this time as flowing off the entire drainage area of 122,200 acres to Deanston, was 3,820 cubic feet per minute; and the quantity due to Loch Katrine district was, as apportioned by Mr. Bateman, 1,700 cubic feet per minute. This gives 37 cubic feet per minute per 1,000 acres, and applying this to Loch Katrine alone we get 864 cubic feet per minute, or 1¼ million cubic feet per day as the entire yield of the district. Then, supposing the store of 650 million cubic feet in the lake to have been full at the beginning of this period, and adding the yield as above, the quantity that could have been supplied was 48 million gallons per day for 100 days. But as it is very unlikely in such a year that the store would be full at the commencement of the dry period, or that the full supply could have been given from the natural streams without storage immediately after the 100 days had passed, there seems no doubt that the full supply from these works would have failed that year.

Mr. Bateman, in his own calculations for that year, gives, as the total yield of the Loch Katrine *district* (which includes Loch Venachar), for that period 71,500,000 gallons per day, and if the original proposals had been carried out to give half this to the mills on the river Teith, he admits the quantity left for Glasgow would have been only 35¾ million gallons per day. So that, even if the 48 millions could have been supplied for 100 days of that year, it must have been at the sacrifice of the compensation water sent down the Teith, which would have been only 23 or 24 instead of 40 millions of gallons per day as now stipulated.

I conclude from these data that the Loch Katrine Works in seasons of excessive drought, and with their present storage, may be reduced to less than 30 million of gallons per day, if the full compensation to the Teith is to be continued.

Newcastle-on-Tyne.

The population of Newcastle is now about 200,000, and the quantity of water supplied 5½ millions of gallons per day, or 27½ gallons per head per day.

The original gravitation works constructed in 1846-7-8, at Whittle Dean, were designed for the supply of about 3¼ million gallons per day. The storage capacities of the reservoirs being 215 million of gallons, and the gather 4,340 acres. The storage was therefore equal to 7,900 cubic feet per acre only.

The quantity of water used in the town at the commencement of the works was about 1½ million gallons per day, so that the reservoirs contained 143 days' supply of that quantity, or 66 days' of the full quantity of 3¼ millions per day.

The water was introduced in 1848, and in 1850 the supply failed, and the old pumping establishment from the river Tyne had to be resorted to. Since that period additional storage reservoirs have from time to time been constructed, which have also in dry years failed to provide the necessary supply of water. The latest large store reservoir added to the works was finished and filled in the spring of 1857, and the storage was then 500 millions of gallons, or ninety days' supply of the present quantity. The rainfall of that year in the Whittle Dean district was only 22 inches, and a drought of eight months' duration commenced with the month of December and continued up to the May of 1858, only 3 inches of rain falling during the time. The consequence was, even the increased store was exhausted early in 1857, and was not replenished during that winter; and in 1858 Newcastle had to be supplied from the old pumping works from the river Tyne, which were of necessity again had recourse to.

The present available storage room is still only 500 million gallons, but the gathering ground was increased about the year 1860 to 17,300 acres, which gives a storage capacity of only 4,900 cubic feet per acre, or less than that originally designed.

The quantity of water expected to be obtained has not been realized in dry years. The average rainfall of the district was assumed to be 24 inches, and of this quantity it was expected 12 inches would be available. The rainfall has proved on the *average* of the last 18 years to be 24 inches as taken originally, but the realized quantity of water has in years of drought been little more than 6 inches, or one-fourth only of the average, and half the anticipated quantity.

Feeling that this critical position is unsafe, the company are now erecting permanent pumping works, to pump water from the river Tyne at Newburn, to the extent of 5 million gallons per day.

Bristol.

Bristol was supplied by gravitation works completed in 1851, for bringing water from the Mendip Hills and other springs in Somersetshire. The full quantity proposed to be supplied was 4 million gallons per day. That this quantity could not be realized in cycles of dry years became apparent in 1860, and measures were taken to supplement the supply by pumping from wells on the line of works.

In 1862 the company obtained an Act of Parliament enabling them to construct additional storage reservoirs, but before these could be completed, the rain deficiency in the winters of 1861, 1862, and 1863 had so seriously affected the springs, that it became evident early in 1864 there would be a dearth of water, and recourse was, in that year, had to all the springs and available sources round Bristol, which were temporarily pumped to supplement the gravitation supplies. Notwithstanding these efforts, the city was limited to six hours per day supply for some time; the store of water was exhausted, and the springs did not yield more than 350,000 gallons per day.

The result of this experience has been the carrying out of a pumping project for obtaining a permanent supplementary supply of water from springs about eight miles from Bristol.

These works are completed and will be resorted to on the approach of dry seasons.

The additional store reservoir has also been completed, and the total storage for Bristol (apart from the compensation storage for mills) is 350 million gallons, or 88 days' supply of 4 million gallons per day.

General Conclusions.

The general conclusions to be drawn from the data I have given in the preceding pages respecting the largest gravitation water supplies in this country, are as follows:—

That none of the works alluded to have completely fulfilled the anticipated results.

Manchester and Glasgow are favourable examples of gravitation works, but exhibit signs of deficiency when tested for cycles of dry years; and of the *five* large towns alluded to, *four* have already erected or are erecting, pumping works in aid of the gravitation supplies.

There is not yet sufficient experience of the variations of rainfalls to arrive at any fixed data for guidance as to the probable minimum quantities in cycles of years; for instance, taking the recorded rain at Greenwich from 1817 to 1867, there is only one example of five successive years which were all below the average fall, viz. 1854 to 1858 inclusive, in which only 100 inches of rain fell. The average fall for the 51 years being 25¼ inches, there was actually a deficiency of 26 inches of rain in these five years, or one whole year's rain. This having occurred only once in 51 years, proves that much longer experience is required to know the various fluctuations that may occur.

In the case of the Glasgow Works, the Deanston observations on the river Teith showed that in the year 1826 the river was lower than at any other period during the observations. I do not know how long before that year the observations extended, but assuming them as commencing in 1825, this case gives only one year in a cycle of 40 or more years as an extreme example.

Again, in the Newcastle case there has since 1848, or during 20 years, been but one example of extreme drought, viz. that of 1857-8, in which only 3 inches of rain fell in eight months.

Other cases could be cited, but these are sufficient to show that the possible variations of rainfall in cycles of years are not yet sufficiently known to fix the absolute minimum quantities of rain for any given district. What has occurred only once in 50 years may occur to a still greater extent during the next 50 years; and when it is considered that these periods of drought are the only real guides as to the efficiency of gravitation waterworks, it is evident that past experience has been insufficient, and that failures have in consequence occurred.

There is also a deficiency of experience with regard to the quantity of water that can be realised from a given rainfall. The rain available for gravitation waterworks, more particularly when a large proportion of the water is from springs, falls almost entirely in the *winter months*, and a deficiency in *winter* rains, although the whole year's rain may be equal to or greater than the average fall of the district, occasions a falling off in the quantity of water in the streams and springs. This is more particularly the case when two or three *dry winters* follow in succession, and the quantity of water realized from a given rainfall of one such year does not apply to the second, which produces a still smaller proportion—for instance, at Liverpool (as reported by the Corporation Engineer), "in 1862 the rainfall was "48·51 inches, the ratio of impounded water to the rain-"fall was 82·63 per cent. In 1865, when the rainfall was "34·8 inches, the proportion of available water flowing off "was only 67·12 per cent.; so that, apart from the "deficient rainfall, that which did fall yielded less by "15·51 per cent. than the rainfall of 1862." Again, at Newcastle, a rainfall of 26 or 27 inches; that is, two or three inches above the average, produces water to the extent of somewhere about 60 per cent. of the fall, while in the year 1850, in which 17·68 inches only fell, the proportion realized was only 6¼ inches, or 35 per cent. of the fall.

Thus, it appears that, basing calculations on *average* falls of rain is erroneous; the minimum quantities only should be depended upon; but, as I have before stated, there is yet no experience sufficient to show what are the minimum falls in a given district, nor what proportion of such falls would be available.

The question of storage is, of course, an important element in gravitation works, and from past experience it is plain that complete security against want of water in exceptionally dry years, could only be attained by storing all the flood waters of two or three successive winters, or, in other words, providing storage for 300 or 400 days' supply to the district.

This matter was well explained by Mr. Homersham, C.E., in a report on the supply of water to Manchester in 1848, in which he states generally that if the whole quantity of water collected in wet years be not used, then the quantity of water that could be regularly yielded by the reservoirs would depend upon the depth of rain falling on the gathering ground and flowing off it in the *average* of years, since the water falling in wet years would be stored from wet to dry years. The size of such reservoirs must, however, be *very large*, as they must be sufficient to contain the superabundance of a succession of wet years, in order to compensate for the deficiency of a succession of dry ones.

The axiom in mechanics, that the strength of a beam is the strength only of its weakest part, applies also to gravitation waterworks, their real strength or power of supply being only the *minimum quantity they may be reduced to*. To be absolutely safe for all periods, it would appear that they ought to be made capable of supplying in years of average rainfall twice the quantity of water required, in order to be equal to meet the deficiency of a minimum year.

I am, &c.
John Taylor.

Great George Street, Westminster,
9th June 1868.

APPENDIX BC.

Report on the Drought of 1868 as regards its Effects on Gravitation Water Supplies to Large Towns.

To the Chairmen of the London Water Companies.

Gentlemen,

In pursuance of instructions received from you on the 16th ult., to inquire into the effects of the late dry season on gravitation water supplies obtained from water-sheds or drainage grounds, I visited various towns reported to have suffered from deficient water supply during the summer and autumn of the present year, and have to lay before you the following results of my investigation:—

Manchester.

Towards the end of July the corporation of Manchester became alarmed at the prospect of a failure in the water supply, and issued the following public notice:—

"*Manchester Corporation Waterworks.*—Tubes for watering gardens and other purposes.—In consequence of the number of persons who are illegally using tubes, for watering gardens and other purposes, notice is hereby given, that under the provisions of the Manchester Corporation Waterworks Act, all persons using such tubes without having made an express agreement in writing with the corporation, are liable to a penalty of 40*s.* for each offence, and that the penalties will in all cases be strictly enforced.

"By order (signed) Joseph Heron, Town Clerk,
"Town Hall, Manchester, July 24, 1868."

The "Manchester Courier" of August 1, contained an appeal to the water consumers as follows:—

"*The Water Supply of Manchester.*—We have been requested by the mayor to publish the following:—The extraordinary and unlooked-for continuation of the heat and drought has compelled the Waterworks Committee carefully to consider their position, and the expediency of taking steps to economise the consumption of water, and to ward off the possibility of any absolute failure in the supply. Every individual is deeply interested in and bound to aid the corporation in successfully accomplishing their object. We understand that it has been decided at an early period (of which, however, public notice will be given) to stop the supply of water during the night; and also to make, if possible, an amicable arrangement for a reduction in the quantity of water daily sent down the river; and it has also been decided to recommend that the watering of the streets shall for the present be entirely discontinued. There is, we are glad to believe, no ground whatever for any alarm; nor, with the aid and co-operation of the inhabitants generally—which, if only out of gratitude for the blessings heretofore enjoyed, the corporation have a right to expect—need there be the least apprehension that any but comparatively trifling inconvenience will be sustained as the consequence of the present extraordinary season. The inhabitants may rely upon having water during, at any rate, 12 hours of each day, and therefore there will be no cause whatever—nor indeed any excuse—for any waste, by making other than the smallest provision for the time when the water may be off. It needs hardly to be pointed out that the use of water for any purpose not absolutely required (such, in fact, as baths, watering gardens, and many other purposes) ought for the present to be discontinued. Every individual is deeply interested in the success of the efforts being made by the corporation to guard against the possibility of there being any interference with such a supply of water as may be absolutely required for the comfort and health of the inhabitants."

In pursuance of this general intimation to the inhabitants of Manchester, the following official public notice was issued the week following:—

"*Manchester Corporation Waterworks.—Public Notice.*—Notice is hereby given, that in consequence of the unprecedented and still-continuing *drought*, the Waterworks Committee have, in addition to other steps being taken for economising the consumption, determined that on and after Monday the 3d day of August inst., and until further notice, *water* shall be supplied only between the hours of six o'clock in the morning and six o'clock in the evening of each day, within the limits of the supply of the Manchester Corporation.

"The committee consider that it is their paramount duty, even at the risk of some present inconvenience, to guard against the possibility of their being unable to supply to the inhabitants the water absolutely required for health and comfort; and they confidently appeal to all to assist them in economising in every way the consumption; and, as the water will be certainly supplied during the hours named, not to cause waste by making undue and unnecessary provision for possible requirements during the time the ordinary supply will cease.

"Dated this 1st day of August 1868.
"By order of the Waterworks Committee.
"(Signed) Joseph Heron, Town Clerk."

In addition to the restrictions in the use of water above alluded to, viz., stopping the street watering and limiting the time of supply to 12 hours per day, the Waterworks Committee effected an arrangement with the mill-owners on the river Etherow to reduce the quantity of compensation water daily delivered from the store reservoirs for uses of the mills, from 15,000,000 of gallons per day to about 7,000,000 of gallons per day, thus conserving for the use of the town nearly 8,000,000 of gallons per day. This arrangement commenced from 10th August, and continued in force for about eight weeks, during which time 384,000,000 of gallons were brought from the mills for the use of the Manchester Waterworks district.

Notwithstanding, however, this limitation to the mills, the store of water continued to decrease, and the following notices were issued to large consumers:—

"*Town Hall, Manchester, August 4th*, 1868.—I am directed by the Waterworks Committee to inform you that in consequence of the present unprecedented drought, the supply of water to your works will be diminished to one-half the quantity that you used during the last quarter. I send you this communication in order that your business arrangements may be as little interfered with as possible.
"(Signed) Joseph Heron."

The principal hotels in Manchester were also cautioned upon the subject, and the following notice was posted in all the bedrooms of the Queen's Hotel:—

"*Notice.*—Owing to the scarcity of water, visitors are respectfully requested not to waste any. Sponge baths one shilling; all other baths will be discontinued."

About the middle of September, it was reported that the store reservoirs, notwithstanding the restricted consumption, both to the mills and the town, contained only about five weeks' supply, and the Waterworks Committee issued the following notice, dated 17th Sept.:—

"*Manchester Corporation Waterworks.—Public Notice.*—Notice is hereby given that in consequence of the still-continuing drought, the Waterworks Committee have, in addition to other steps being taken for economising the consumption, determined that on and after Monday, the 21st September inst., and until further notice, water shall, within the limits of supply of the corporation, be supplied only between the hours of six o'clock in the morning and two o'clock in the afternoon of each day. In order to guard against the possibility of their being unable to supply the inhabitants the water absolutely required for health and comfort, the Waterworks Committee again confidently appeal to all to assist them in economising in every way the consumption; to use any pumps or other sources of supply which may in any case be available; and not to cause waste by making undue and unnecessary provision for possible requirements during the time the ordinary supply will cease.

"Dated this 17th day of September 1868.
"By order of the Waterworks Committee.
"(Signed) Joseph Heron, Town Clerk."

Again, on the 19th September, the Waterworks Committee issued the following circular:—

"*Supply of Water in Manchester.*—The drought still continues, and it has long ceased to be possible to anticipate or speculate with any degree of certainty as to the time when we shall have in this district any rainfall which will materially increase the storage in the corporation reservoirs, upon which so enormous a population is dependent for the supply of water absolutely necessary for health and comfort.

"The drought has now, with little or no material interruption, continued for the unprecedented period of nearly six months, and it is hardly necessary to say that the Waterworks Committee have, for many weeks past, been compelled to consider in what way the consumption can be reduced, and been watching with the greatest anxiety the gradual but constant diminution of the water in the reservoirs.

"As already announced, one half only of the compensation water required to be sent down the Etherow for the supply of the mills has for some weeks been furnished. A further reduction may become necessary, but unless and until absolutely compelled, the committee are most unwilling further to interfere with such supply. The committee

have every reason to be satisfied with the disposition generally manifested by the occupiers of the mills for whose benefit such compensation water is secured by Act of Parliament, in every way to meet the corporation under circumstances of unprecedented difficulty, fully recognizing the fact that, without abandoning their claims to reasonable compensation for any actual loss or extra expense sustained, the supply of water for the requirements of the inhabitants for domestic consumption must and ought to be the paramount consideration with the corporation.

"At a meeting of the committee held yesterday it was determined to shorten the hours of supply, and to supply water throughout the city and district dependent upon the corporation, from and after Monday next the 21st instant, only between the hours of six o'clock in the morning and two o'clock in the afternoon; and at the same time still further to reduce the quantities of water supplied for trading purposes.

"When the inhabitants consider the reports appearing constantly in the papers of the very short period (varying from one or two to three or four hours) during which water is supplied to the inhabitants in neighbouring towns, and in other cases of the entire failure of all supply by the authorities, they have every reason to congratulate themselves that the corporation are after such a period of drought, and notwithstanding the large demands upon their works, still able to propose to supply water during eight hours of each day, and thereby to afford an ample opportunity to all to obtain the quantity of water absolutely required. How long this great boon may continue in the possession of the inhabitants will, if the drought continue, to a great extent depend upon themselves. The utmost economy in the use of water must be exercised. Where any other means of supply, either from existing pumps or otherwise, are available, such means ought to the largest extent possible to be made use of, in order to lessen the consumption of the water of the corporation.

"The committee have every reason to believe, from the diminished consumption which has resulted from the shortening of the hours of supply, that the inhabitants have willingly and effectively carried out the desire of the corporation, that they should exercise the strictest economy in the use of the water; and with such continued co-operation and assistance, the committee trust that they may yet be enabled to pass through this most extraordinary ordeal without limiting to a greater extent than is now proposed the supply of water to the inhabitants."

Amongst other steps taken by the Waterworks Committee for conserving the water, was the putting in force of the provisions of their Acts of Parliament against the waste and misuse of water by the inhabitants, as indicated in the following paragraph, which appeared in the "Manchester Courier" of August 6:—

"*Wasting Water in Manchester.*—Twenty-two cases of offences against the Waterworks Acts were heard by the Waterworks Committee of the Manchester Council on Monday last, of which three were fined for using tubes for watering gardens without agreement, six for taking water illegally, two agreed to take the water, one excused, one plumber struck off the list, one consumer cautioned against waste, two reprimanded, one adjourned for further inquiry, four for wasting water by tubes being left running on the grass, and one for further inspection. Total amount of penalties, 16*l.* 15*s.*"

Again, in the paper of August 19th, it was reported as follows:—

"*Misuse of Water in Manchester.*—Eleven persons were brought before the Manchester Waterworks Committee on Monday for offences against the Waterworks Acts, of which six were fined for using tubes for watering gardens and other purposes without having made agreements, and two for obtaining water illegally; one agreed to take water, one plumber was authorized, and one suspended. Total amount of penalties, 7*l.* 0*s.* 4*d.*"

These proceedings, although there can be no question as to their propriety at the time, serve to show the exigencies of the case, and the stringency of regulations the enforcement of which we are as yet happily ignorant of in London.

The limitation of the supply to eight hours daily continued in force from 21st to 29th September, when the 12 hours' supply was again resorted to, and this continued to the 26th October, when the full supply was afforded to the district. Thus, for 76 days it was limited to 12 hours per day, and for seven days to eight hours per day.

The ordinary supply to the Manchester district, which includes besides the towns of Manchester and Salford a large outlying population extending to many neighbouring towns, averages about 15 million gallons per day, and the compensation water sent down the river Etherow is nearly 15 millions per working day, and spreading the latter over seven days per week, the average daily draught from the works is about 27 million gallons per day. It is difficult to ascertain the exact quantity during the limited supply, but from data obtained I estimate that during the 12 hours' limitation the district supply was reduced from 15 millions to about 11 millions per day, and during the eight hours' supply to about 8 millions of gallons per day, or about 13½ gallons per head per day of the population for all purposes, including the limited supply to manufactories.

When the restriction to the mills took place 8 millions of gallons per day were reserved from compensation water for the district supply, and upon these data it appears that the total deficiency of the ordinary supply of water from the Manchester Gravitation Works was 737 million gallons spread over 83 days, or nearly 9 million gallons per day.

It should be mentioned that the quantities distributed, as above stated, were increased to the extent of about 550,000 gallons per day pumped from the old well at Gorton, which was put in requisition in aid of the gravitation supply from 12th August to 8th October.

The two new compensation reservoirs in course of construction below Rhodes Wood reservoir, alluded to in my former report, are designed to hold 750 million gallons of water; it would therefore appear that had these reservoirs been filled before the commencement of the drought the full compensation water to the mills could have been sustained throughout, and a further quantity been available for the district supply.

It does not appear that the restriction of the hours of supply caused any serious want of water for purely domestic use; on the contrary, it is believed that more water than usual was consumed in the houses of the middle and lower classes, where no cisterns existed for storing the day's supply, and for this reason—that during the known hours of service all available receptacles for water were filled and kept in reserve for night use, and thus generally a superabundant provision was made, which was thrown away next day when the water was again turned on at the mains. The deficiency was chiefly observable in the curtailment of the comforts and benefits attending the ample use of water for street watering and for washing courts, and for other sanitary purposes, and for watering gardens, for private baths, waterclosets, and domestic washing; and in such curtailment, together with the saving of night waste and the diminished supply to large consumers, lay the real saving of water during the limited supply. Had a cistern existed in every house, all the trouble and annoyance attending the temporary storage of water in every variety of receptacle would have been avoided.

Salford.

The borough of Salford is supplied with water from the Manchester Works, the water being measured and charged by meter to the corporation. The water district comprises about 77,000 inhabitants, and the usual supply is about 1¾ millions per day, or about 22 gallons per head per day for all purposes. The domestic supply is stated to be about 15 gallons per head per day.

The water service was restricted in Salford at the same times and to the same hours per day as in Manchester, public notices to that effect being issued. The restriction to 12 hours per day reduced the quantity from 1¾ millions to 1¼ millions per day, and for eight hours per day service the quantity was reduced to about 900,000 gallons, or 13½ gallons per head per day for all purposes. The same remarks on the domestic supply during the restricted hours of service apply to Salford as well as Manchester; but seeing that the whole supply was reduced to 13½ gallons per head per day for all purposes, and that the manufacturers had no other limitation than the hours of supply, the purely domestic service must have been reduced to eight or nine gallons per head.

Stockport.

Stockport is supplied with water partly from a watershed and store reservoir in Lyme Park, about six miles distant, and partly from the Manchester Works under an agreement with the corporation to provide any quantity of water required, not exceeding 1 million gallons per day. The full supply to Stockport is about 1½ million gallons per day to 60,000 persons, or 25 gallons per head per day for all purposes.

The drought was felt equally at Stockport as at Manchester, and the water service was restricted about the same times and to the same hours as in that district. The following public notice was issued:—

"*Stockport District Waterworks Company.—Public Notice.*—Notice is hereby given that owing to the long continuance of the drought, without any appearance of its cessation, it is incumbent on all parties to economise the use of water; and if the inhabitants will restrict themselves to the use of *six or seven gallons a head per day*, the

company will be enabled to supply them, no matter how long the drought continues. But in order to ensure a diminution in the quantity of water used, they must discontinue the supply at night, and probably during a portion of the day, if it is found that the water used still exceeds the quantity named. On and after Thursday the 6th day of August instant, and until further notice, water will be supplied between the hours of 7 o'clock in the morning and 7 o'clock in the evening of each day. The company trust the inhabitants will assist in every way in economising the consumption.

"Dated this 5th day of August 1868.

"By order, GEORGE MATHER, Secretary."

In the course of September it became apparent that the Lyme Park store would fail, and the quantity supplied by the Manchester corporation being reduced to about 200,000 gallons per day, recourse was had to wells existing at two old pumping stations near the town, from which a part of the original supply of water to Stockport was obtained, and from these wells a limited quantity per day was pumped in aid of the supply from the Manchester Works.

ROCHDALE.

The Rochdale Gravitation Works supply a population of about 40,000, with an ordinary supply of about 750,000 gallons per day, or 18¾ gallons per head per day, there being few meter supplies, and only about 400 waterclosets, out of 13,000 services. The capacity of the four store reservoirs attached to the works is 172 million gallons, but in March last the largest, containing when full 47 million gallons, became defective, and the water was run off, so that the summer store was considerably reduced; the gathering ground is from 600 to 700 acres in extent.

In apprehension of the effects of the drought, the following notice was placarded about the town:—

"*Rochdale Water.*—Notice is hereby given, that during the droughty weather now prevailing, *a supply of water* from the Rochdale Corporation Waterworks will be afforded between the hours of 7 *and* 11 *o'clock in the forenoon only* of every day after Friday next.

"By order, ZACH. MELLOR, Town Clerk.

"Rochdale, 25th June 1868."

Notwithstanding the restriction of the water supply as above intimated to four hours only per day, which continued for about 15 weeks, the store of water was entirely exhausted during the second week in October, and the town would have been almost without water, but that recourse was had to pumping from Dearnley Colliery, about two miles from Rochdale. This temporary source was sufficient to keep the town supplied with water for domestic wants.

An extension Act was obtained in 1866, and additional works are in course of construction.

BURY.

The town of Bury is supplied with water by the Bury and Ratcliffe Waterworks Company. The inhabitants supplied number about 60,000, and the ordinary quantity of water consumed is rather less than 1 million gallons per day, or 16⅔ gallons per head per day, there being few waterclosets, and little street watering. There are four store reservoirs attached to the works, having a capacity of 275 million gallons, with a water-shed of about 2,000 acres. Compensation water to mills is given out of this store to the extent of 1½ million gallons per day, so that with the town supply the full draught is nearly 2½ million gallons per day, and at this rate the reservoirs hold a little over 100 days' supply.

The store of water ran so low towards the end of August that it was reserved entirely for compensation to the mills, as the company were able to obtain from a neighbouring works (the Haslingden and Rawtenstall Water Company) a supply of 400,000 gallons per day for the town of Bury. This provided a quantity of rather less than seven gallons per head per day, which sufficed to supply purely domestic wants; but for baths, manufacturing, or trade uses there was no water. This must have been severely felt by manufacturers, as in ordinary times a good deal of water is taken for steam purposes and dyeing. The company were enabled to continue the full compensation water to the mills, and thus avoid the payment of penalties; but at the lowest water time there were not more than two or three days' water left in store. The short supply of water to the town continued for five weeks.

BOLTON.

The population of Bolton supplied with water is about 100,000, and the ordinary quantity supplied about 2,500,000 per day, or about 25 gallons per head per day for all purposes. There are four store reservoirs belonging to the works, having a combined capacity of 300,000,000 gallons, or 120 days' supply.

The supply to the town was reduced on the 9th September to one-half the ordinary quantity, and continued so till the 12th October, or about five weeks. The service was not limited to any stated time, but was given out at the discretion of the engineer, in different parts of the town, at different hours of the day, in the manner of an intermittent supply. No public notices were issued.

The compensation water to the mills is given from separate reservoirs for that purpose only, which are under the control of the millers.

LIVERPOOL.

Liverpool is supplied with water on what may be called the *mixed* system, partly from the Rivington Gravitation Works, and partly from a number of wells in the more immediate neighbourhood, sunk into and deriving water from the new red sandstone.

By a recent Act of Parliament the corporation are authorized to shut off the water at any time, as circumstances require, and during the whole of this year the district has not had more than 12 hours per day supply of water; in fact the supply is now practically intermittent. Notwithstanding this, however, the drought was seriously felt, and on the 22d August the service was limited to nine hours per day, and again, about the 9th of September, to seven hours only per day, at which it was still maintained at the date of my inquiry (31st October).

The quantity of water supplied before the limitation to nine hours' service was about 16,500,000 gallons, or about 27 gallons per head per day, of which about 6,000,000 were pumped from the wells, and 10,500,000 provided from the gravitation works.

The quantity of water supplied after the limitation of service to seven hours per day was about 13,000,000 gallons (or 21 gallons per head per day), of which 7,000,000 were supplied from the gravitation works.

The compensation water afforded to rivers and mills was originally 8,300,000 gallons per day continuously, but since September last year it has been reduced to about 6,500,000 per day, by the purchase of 1,850,000 gallons per day, and this additional quantity has thus been available during the late dry season.

The present full store of water at Rivington is 3,100 million gallons, and the quantity was reduced in the drought down to 700 millions, or, including the compensation, to about 50 days' supply of the quantity consumed during the seven hours' service.

Liverpool has not seriously suffered from the drought; the domestic supplies have been influenced in the same manner as described in Manchester, by the consumers making provision against the shutting off of the water by the temporary expedients of storing in tubs, &c. The limitation of the hours of service to seven per day only reduced the consumption by about 3½ million gallons, and could the extent of the drought have been foreseen, the 12 hours' supply might have been continued throughout the entire season, without altogether exhausting the gravitation store of water.

PRESTON.

The town of Preston, containing a population of about 93,000 inhabitants, is supplied with water from a gravitation work in the hands of the corporation. The storage reservoirs, three in number, have a total capacity of 265 million gallons, with a drainage ground of 2,878 acres. The ordinary summer supply to the town is about 2¼ million gallons, or 24 gallons per head per day for all purposes, or 18 gallons per head per day, exclusive of trade supplies. The store reservoirs, therefore, contain about 120 days' supply of water. At the end of June fears were entertained of the reservoirs running dry, and a temporary source of supply was looked for. At the end of July it was estimated that only 23 days' water was left in store, and the Water Committee confirmed the proposed arrangement for pumping water from the river Hodder, a tributary of the Ribble. In about three weeks the temporary works were brought to bear, and the pumping was commenced on 27th August, at which time the reservoirs were practically dry. These works were costly, as the temporary source of supply was 13 miles distant from Preston, and pipes and open cutting for that length of aqueduct, besides the steam engines and pumps, had to be resorted to. The water was lifted 120 feet from the river, and then flowed through the temporary aqueduct to one of the store reservoirs, and the quantity pumped was sufficient to maintain the supply of the town, which was thus continued constantly throughout the drought. The pumping was carried on from 27th August to 24th October, or 58 days.

Notice of application to Parliament for extension of works is given for the ensuing session.

Kendal.

This town is supplied with water from a gravitation work belonging to the Kendal Gas and Water Company. The population is about 12,000, and the works consist of two store reservoirs, with a joint capacity of 32 million gallons, and a drainage ground of 240 acres, entirely devoted to the town service. The ordinary quantity supplied is 200,000 gallons, or 16⅔ gallons per head per day, and the full store contains 160 days' supply.

On 19th August the reservoirs were exhausted, and the town was left without any supply of water for four or five days. A temporary pumping work to supply water from the river Kent, about a mile and a half above the town, was then hastily carried out, and about 160,000 gallons per day thus provided; and this means of supply was continued for five weeks. I was informed that the company contemplate making a permanent pumping work from the river, in aid of the gravitation supply during seasons of drought.

Newcastle-on-Tyne.

The Newcastle and Gateshead Water Company now supply their district on the mixed system, viz., from the Whittle Dean Gravitation Works, and from the new pumping works lately established near Newburn, to pump water from the river Tyne above tidal influence. The district has not been short of water, because the deficiency of the gravitation supply was made up from the pumping works. The quantity ordinarily supplied at present is 5½ to 6 million gallons per day, to a population of 170,000 to 180,000 people, or about 32 gallons per head per day.

The service throughout the drought has been 3 millions of gallons, drawn from Whittle Deen store reservoirs, and 3 millions pumped from Newburn. With this draught upon the reservoirs they have been reduced from the full capacity of 530 million gallons to 78 million gallons, the decrease in the store continuing down to the 2d November, notwithstanding the rains of September and October.

The supply of water from these gravitation works failed during the drought of 1857 and 1858, as alluded to in my former report, the deficiency of water being then temporarily made up by pumping from the Tyne. The drainage ground has, from time to time, been increased to upwards of 17,000 acres, but even with this increase, the gravitation supply alone would have failed to afford a full supply to the district for many weeks during the present summer and autumn; this being proved by the fact that a draught of 3 millions per day reduced the store to only 25 days' supply, and, as a matter of course, a draught of 5½ millions would have exhausted it early in the summer

Bradford.

The population of Bradford within the limits of the water district is 250,000, of which about 150,000 only are present supplied from the works, viz., 90,000 on the low level, and 60,000 on the upper level. The present storage capacity of the reservoirs attached to these gravitation works is 300 million gallons for the low level, and 85 millions only for the upper level, the water being gathered from 9,000 acres for the low, and 900 acres for the upper level. It will be convenient to allude to these as two separate water supplies, as they failed at different periods, the higher level suffering much more than the lower.

The low-level district has an ordinary supply of 4½ million gallons per day in winter and 6 millions in summer, say 5½ millions per day average; and thus the low-level storage is equal to about 160 days' supply. About the middle of June it became doubtful whether the full supply could be maintained, and the quantity was diminished successively to 4½, 3, and 2 million gallons per day, the latter being supplied in six hours only, to which the time of service was gradually diminished.

The upper-level district has an ordinary supply of 1 to 1½ million gallons for winter and summer respectively; and the storage capacity for this is therefore only about 68 days' water. On 19th June this store was practically exhausted, and the reservoir was shut off on 20th June, and during the following 16 weeks the water was only turned on once a week (on Saturdays), the quantity accumulated during the week being then distributed—a quantity equal to about a full day's supply.

No compensation water for mills was given out of the town reservoirs, as there are separate reservoirs for this purpose under the control of the millers themselves.

The following public notices were issued:—

"*Bradford Waterworks.—Public Notice.*—In consequence of the long-continued dry season, the store of water in the Stubden reservoir has been so much reduced, that the full and regular supply of water throughout the high-level district cannot be continued. The water will be shut off on Saturday, 20th June instant, and will be turned on again on the Saturday following, and on every succeeding Saturday only, so long as the dry season continues. The places to which this notice applies are the high-level parts of the borough—Thornton, North Bierly, Wibsey, Gomersal, Birstal Tong, Tyersal, Pudsey, and Eccleshill.

"By order, Charles Gott, Waterworks Manager.
"19th June 1868."

"*Bradford Waterworks.—Public Notice.*—In consequence of the continued dry season, and the diminished supply of water to the reservoir, the Waterworks Committee are under the necessity of urging upon all consumers of water to take every precaution to prevent *any waste of water*. And they are furthermore obliged to prohibit, from the date hereof, the use of any portable pipes or other means for the purpose of *watering gardens, washing causeways, windows*, or any similar use.

"All persons are hereby requested to give information at this office of any waste of water being permitted, or of any such use for the aforesaid purposes of gutta percha or other pipes. It is hoped that there will be no failure in the supply throughout the low-level district, if proper care is taken by the consumers, but that, of course, will be dependent on the length of time the dry weather may still continue.

"By order, Charles Gott, Waterworks Manager.
"Waterworks Office, June 26th, 1868."

"*Bradford Waterworks.—Caution as to the use of Water.*—The Waterworks Committee feel compelled, in consequence of the continuation of the drought, to call attention to the necessity for extreme caution in the use of water throughout those parts of the district which are supplied from the low-level service.

"The committee regret that there has been cause for reports to be made to them of the unnecessary use of water by several persons in the town, notwithstanding the previous notices.

"The committee request every person to exercise the greatest care in the use of water, not only to prevent waste, but also to limit its use to purposes of absolute necessity.

"The committee have reason to hope that with the co-operation of the inhabitants, and with the exercise of care on the part of every consumer, they will still be able to maintain the supply throughout the dry season.

"By order, Charles Gott, Waterworks Manager.
"July 1868."

"*Bradford Waterworks.—Notice as to the use of Water.*—The Waterworks Committee feel it to be their duty to make a further appeal to the inhabitants generally to reduce the consumption of water throughout the town and district—both for domestic use and for trade purposes—to the smallest quantity practicable.

"The reduction in the use of water, and the care which has been taken since the previous notices, have had the effect of enabling the committee to continue the supply up to the present time without interruption, and the committee still hope that, *with a further effort on the part of the inhabitants*, a failure of the supply will be entirely avoided.

"It is also very important that everyone should be careful to keep their water taps and fittings in good repair, to prevent the loss of water from waste.

"By order, Charles Gott, Waterworks Manager.
"Swaine Street, 11th August 1868."

The town of Bradford has, therefore, had 60,000 of its inhabitants reduced to one day's water supply per week, for 16 weeks, and 90,000 reduced gradually, during the same period, down to six hours' supply per day, which continued for five or six weeks. A great deal of water is ordinarily supplied for manufacturing purposes, which of course have been most seriously affected. These waterworks have only been in operation for eight years, and have not before failed; new reservoirs are now in course of construction, and notices are issued for application to parliament for further extension of works.

Halifax.

The town of Halifax is supplied with water from gravitation works in the hands of the corporation, the population supplied being about 50,000. The reservoir capacity is 280 millions of gallons, and the ordinary supply to the district is 1½ to 2 million gallons per day, a large quantity of water being supplied for manufacturing purposes. Compensation water for mills, to the extent of 1 million gallons per day, is given out of the Ogden reservoir, under heavy pecuniary penalties in case of failure. Thus the total draught on the works in ordinary times is nearly 3 million gallons per day, and the full store of water is therefore equal to about 100 days' supply.

In the month of May the drought was beginning to be felt, and the store of water to be reduced; and the Waterworks Committee on 11th resolved to limit the domestic supply to 14 hours per day, viz., from 5 a.m. to 7 p.m., and to restrict the trade supply to not more than 30,000 gallons per day to each consumer.

On the 19th May it was further resolved to limit the trade consumers to 15,000 gallons per day each, which con-

tinued to the 29th June, when it was again resolved to limit them to 3,000 gallons only per day each.

On the 14th July the following public notice was issued, to limit the domestic supply to 10 hours per day, a resolution of the committee being passed at the same time to further reduce all trade supplies to 2,000 gallons per day to each consumer:—

"*Halifax Waterworks.—Notice* is hereby given that on and after the 16th instant the supply of *water for domestic purposes* will be limited to 10 hours per day, namely, from the hour of 5 o'clock in the morning until 3 o'clock in the afternoon. Persons having boilers in connection with kitchen ranges are warned not to allow such boilers to become empty, in order to avoid explosion.

"The public are cautioned against the *waste of water*, and the use of the hose and jet is strictly prohibited.

"Persons disobeying this order render themselves liable to heavy penalties.

"By order, JAMES EDWARD NORRIS, Town Clerk.
"Town Hall, Halifax, 14th July 1868."

Ten days later, viz., on 25th July, it was resolved to limit trade consumption to 1,000 gallons per day to each consumer, the probability of the total suspension of such supplies being threatened; and the following public notice was also issued, limiting the time of domestic service of water to six hours per day, namely, from 10 a.m. to 4 p.m.:—

"*Halifax Corporation Waterworks.—Caution.*—Notice is hereby given, that on and after to-morrow, the 26th July instant, the supply of *water for domestic purposes* will be limited *to six hours per day*, namely, from 10 a.m. to 4 p.m.

"The public are earnestly requested to co-operate with the authorities in economising water as much as possible. Any person wilfully wasting water will be punished as the law directs.

"By order, JAMES EDWARD NORRIS, Town Clerk.
"Town Hall, Halifax, 25th July 1868."

Thus the domestic supply of water was limited to 14 hours per day for 66 days, to 10 hours per day for 10 days, and to six hours per day for 86 days, the full supply being only resumed on 19th October; while the supply to large consumers for the important trade of this district was gradually reduced from the first limit of 30,000 gallons per day to 1,000 gallons per day each.

The full compensation water to the mills was continued throughout, and pecuniary penalties avoided; but, on 22d September the entire store of water was reduced to about 22 million gallons, that of the Ogden reservoir being only 11½ millions; so that, apart from the town supply, there were only about 11 days' compensation water left.

On the 28th July a small stream of water began to be used as a temporary aid to the general supply.

The works are now in course of extension, under the powers of an Act of Parliament procured in the session of this present year.

SHEFFIELD.

The population of the town and district of Sheffield supplied with water by the Sheffield Waterworks Company is 210,000, and the ordinary quantity supplied is about 3,800,000 gallons, or 18 gallons per head per day.

The total capacity of the storage reservoirs is 900 million gallons, with a drainage ground of 4,461 acres. The quantity of water given out of the reservoirs for mill compensations is 3,250,000 gallons per day, making the total ordinary draught from them 7 millions of gallons per day, or thereabouts; the full store of water is therefore equal to 128 days' supply.

Sheffield, although supplied by gravitation works, has at no time more than an intermittent service of 12 hours per day, and early in June the drought made it apparent that this could not be prudently maintained, and the hours of service were, on 9th of that month, reduced from 12 to 10. On July 6th the hours of service were further curtailed from 10 to eight, and on August 12th from eight to six; and lastly, on September 2d, from six to four hours' supply per day, the Sunday supply being discontinued on and after September 6th (as per notice below). The quantity of water supplied to the district was at this time reduced from 18 gallons to 11·3 gallons per head per day; and the compensation water to the mills was also reduced during the whole of September to one half the ordinary delivery. Notwithstanding these reductions in the consumption, the store of water became reduced in September to 128 millions of gallons, or 32 days' supply only of the *reduced* quantities, both to the district and the mills.

The following public notices were issued:—

"*Water Supply.*—The stock of water in the storage reservoirs for the use of the town having become so very much reduced in consequence of the unusual drought of this season, the Directors of the Water Company most earnestly request that all consumers will abstain from using the water for any other purposes than those which are absolutely necessary. The Directors think right to give notice that should the present dry weather continue, it will shortly be necessary to restrict the supply of water to three days a week.

"WILLIAM WATERFALL, Managing Director.
"10th August 1868."

"*Water Supply.*—The stock of water in the storage reservoirs for the use of the town having become very much reduced, in consequence of the unusual drought of this season, the Directors of the Water Company, in order to economise the water as far as practicable, have determined to discontinue the supply to the town on Sundays, believing that the absence of water on those days will cause less inconvenience to consumers than restrictions on the working days of the week.

"Notice is therefore hereby given, that the water will not, for the present, be supplied on Sundays.

"The Directors also think right to give notice that, should the present dry weather continue, it will shortly be necessary to restrict the supply of water to three days a week, and the Directors most earnestly request that all consumers will abstain from using the water for any other purposes than those which are absolutely necessary.

"WILLIAM WATERFALL, Managing Director.
"31st August 1868."

The supply to manufacturers was not curtailed beyond the hours of reduced service throughout the district. As the store of water increased, the time of service was lengthened, but the regular supply of 12 hours per day was only resumed on the 9th instant.

Although the hours of service were reduced during September and part of October to one-third or 33 per cent. of the ordinary time, the quantity of water supplied was only reduced from 18 to 11·3 gallons per head per day or 62½ per cent. The supply for purely domestic purposes was therefore not greatly curtailed in quantity, but was attended with all the evils and inconveniences to the consumers before alluded to in the case of Manchester. In fact, in the absence of cisterns for storage, all the towns put on short supply must have been similarly circumstanced as regards the domestic services.

The Sheffield Waterworks have for some years past been in course of extension.

OTHER TOWNS.

In addition to the towns particularly alluded to herein, many others have suffered to a greater or less extent from deficient water supply during the drought of the present year, amongst which may be mentioned Ashton, Staleybridge, Mottram, Oldham, Dewsbury, Warrington, Blackburn, Bacup, Burnley, and Newport in Monmouthshire. Of these towns, however, I have not obtained precise information.

GENERAL REMARKS.

With regard to the rainfall of the present year, the average for 13 localities in the counties of Lancashire, Cheshire, Cumberland, Northumberland, and Yorkshire, for the last 10 months to end of October, has been about 30 inches; and, comparing the results of this year with the averages of the corresponding 10 months for many years past, at places for which I have been able to get such returns, I find the rainfall has been deficient in the proportion of about 40½ inches to 34½ inches, or 85 per cent. of the average. This deficiency, however, does not in itself altogether account for the extraordinary drought that has prevailed, because during the first three months of the present year the rainfall was generally more than an average. It was the singular deficiency of rain in May, June, and July, accompanied with an excess of temperature and evaporation, that caused the exhaustion of the springs, streams, rivers, and stores of water throughout the country.

The general result has been that nearly all gravitation supplies of water, obtained from drainage grounds, have failed in a manner hitherto unprecedented within the known experience of such works, proving that the data on which they have been based have been fallacious, and that the storage reservoirs and gathering grounds of such works must be greatly increased to meet the demands of years like the present.

I am, &c.,
JOHN TAYLOR.

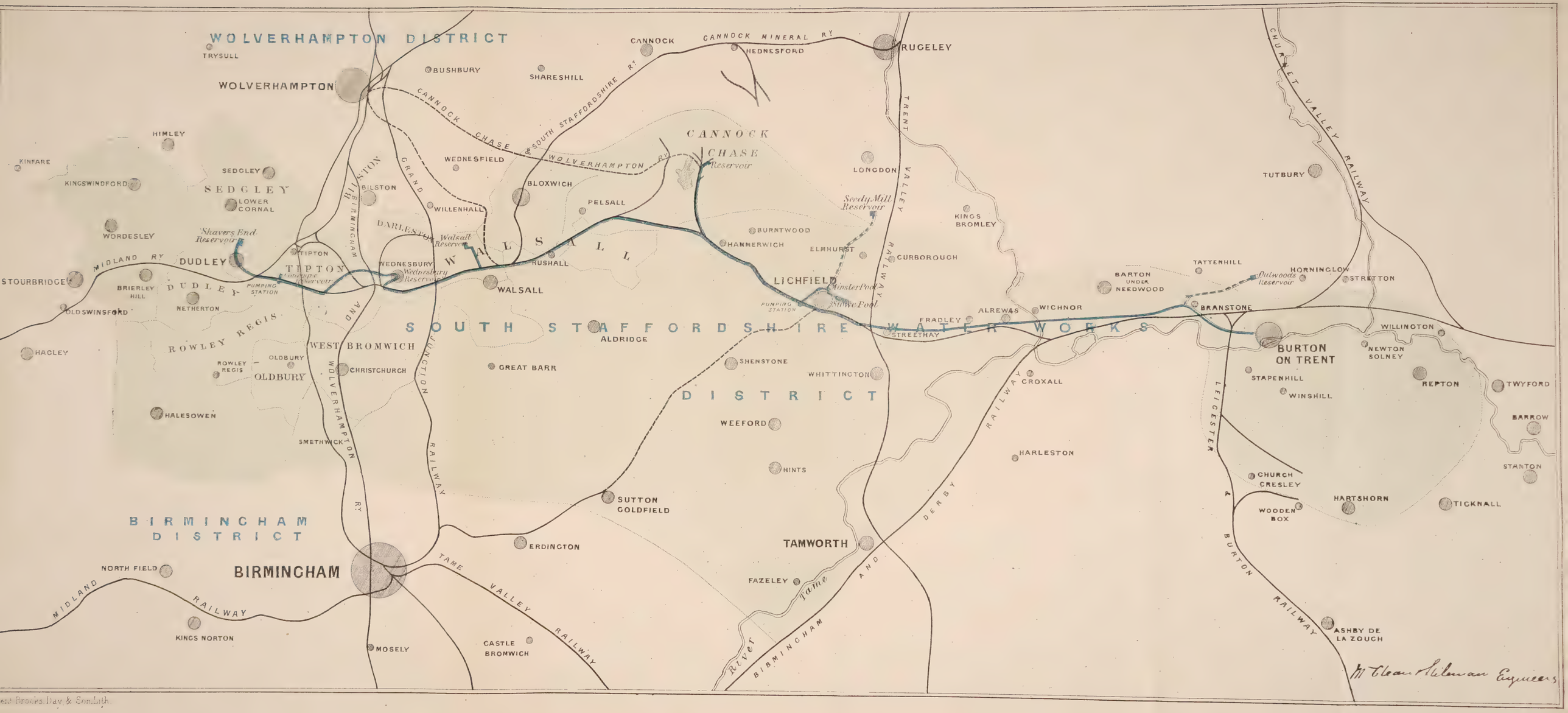
Great George Street, Westminster,
24th November 1868."

SOUTH STAFFORDSHIRE WATER WORKS.

1866.

AUTHORISED DISTRICT COLOURED BLUE.

ROYAL COMMISSION ON WATER SUPPLY
APPENDIX B.D.



ert Brooks, Day & Son, lith.

SCALE OF MILES

MILES ½ 0 1 2 3 4 5 6 7 8 9 10 MILES

APPENDIX BE.

Supplementary Report on the Chemical Quality of Samples of Water collected in the Basin of the Thames.—By Dr. E. Frankland, F.R.S., and Dr. Odling, F.R.S.

To the Royal Commission on Water Supply.

My Lord Duke and Gentlemen,

In our previous report, your attention is called, at page 6, to the circumstance that the Thames is chemically purer at Hampton than at any other part of its course, and that between Staines and Hampton, a distance of only 12½ miles, the water of the Thames suffers a diminution of 3·33 parts of solid residue, of ·044 part of organic carbon, and of ·003 part of organic nitrogen in 100,000 parts of water. Two important tributaries, the Colne and the Wey, entering the river between the points at which the Staines and Hampton samples were taken, it appeared probable that the remarkable amelioration of Thames water between Staines and Hampton was due to one or both of these tributaries.

It hence seemed desirable to make a special investigation of this portion of the river, and, in accordance with your instructions, Mr. Pole collected the following samples on the 28th of October last:—

1. Water from the Thames just below Staines Weir, and above the junction of the Colne. Collected at 11.20 a.m. Temp. of water 8°·5 C.
2. Water from the main stream of the Colne, about 200 yards above its junction with the Thames. Collected at noon. Temp. of Water 8°·0 C.
3. Water from the Wey, about 200 yards below the entrance into it of the Basingstoke Canal, and about half-a-mile above its junction with the Thames. Collected at 2.45 p.m. Temp. of water, 8°·5 C.
4. Water from the Thames, just above the intake of the water companies at Hampton. Collected at 3.45 p.m. Temp. of water 9°·0 C.

The following table contains the results of the analysis of these samples.

	Thames at Staines.	Colne.	Wey.	Thames at Hampton.
Total solid residue from 100,000 parts of water evaporated and dried at 100° C.	31·40	32·14	18·10	29·90
Mineral substances in 100,000 parts of each water:				
Lime	12·63	13·78	5·73	11·85
Magnesia	0·70	·71	·52	·68
Potash	·56	·47	·52	·55
Soda	1·34	1·14	1·35	1·30
Sulphuric acid	3·31	2·10	2·02	2·60
Carbonic acid	9·08	10·50	4·02	8·70
Silica	1·02	·99	1·17	1·21
Chlorine	1·66	1·59	1·83	1·76
Nitrogen as nitrates and nitrites	·173	·302	·090	·205
Ammonia	·004	·017	·005	·006
Organic substances in 100,000 parts of each water:				
Organic nitrogen	·097	·071	077	·057
,, carbon	·304	·282	·307	·263
Hardness in 100,000 parts of each water before boiling	22·0	21·7	10·1	21·6
Ditto after boiling	4·6	3·9	6·1	4·7

The reduced quantities of total solid residue and of mineral constituents in Thames water collected at Hampton, compared with the quantities found in the sample taken at Staines, are satisfactorily accounted for in the above analytical results. They are attributable chiefly to the Wey, which contains a much smaller proportion of these ingredients than does either the Thames or the Colne. On the other hand, the marked reduction of organic carbon and nitrogen, in the Thames between Staines and Hampton, finds no explanation from this supplementary series of analyses inasmuch as both tributaries contain these ingredients in larger proportions than does the sample of water collected at Hampton. As it was thus evident that the amelioration in question did not result from dilution, it was necessary to seek for its cause in chemical action. The effect might be attributed to an oxidation of the organic matter during the flow of the river from Staines to Hampton; but it was not likely that a process which had produced no corresponding effect between Lechlade and Staines should be able to bring about such a remarkable reduction of organic matter in the comparatively short distance of 12½ miles. Moreover there was another and obviously possible cause; viz., the incompatibility of certain kinds of organic matter with the hardening constituents of water—peaty matter, for instance, being rarely or never found abundantly in water containing much carbonate of lime; and we found on mixing a sample of water artificially contaminated by peaty matter with another sample in which bicarbonate of lime had been dissolved, that the mixture soon became slightly turbid, although each sample was previously clear and transparent. Acting upon the suggestion offered by this experiment, we mixed together equal volumes of the clear waters of the Thames at Staines, and of the Wey. Within half an hour the mixed sample had become perceptibly turbid, and after standing for 15 hours, a very marked brownish deposit had subsided to the bottom of the vessel. After filtration the mixed water was submitted to organic analysis. It yielded ·291 part of organic carbon and ·065 part of organic nitrogen. The difference between these numbers, and those yielded by the separate waters, is seen in the following table:

	Organic Carbon.	Organic Nitrogen.
1. 100,000 parts of Thames water collected at Staines and filtered contained	·304	·097
2. 100,000 parts of Wey water collected as described above and filtered contained	·307	·077
3. 100,000 parts of a mixture of equal parts of No. 1 and No. 2 ought to contain	·3055	·087
4. After standing 15 hours, the mixture, after filtration, actually contained	·291	·065
5. Removed from solution by mixture	·0145	·022

Although the reduction of organic matter here effected is not so great as that actually observed in the preceding series of analyses, yet it can scarcely be doubted that the result of our experiment points to the true cause of that greater reduction. It must also be borne in mind that the precipitation of organic matter would probably have been larger if the mixture, instead of standing for only 15 hours before filtration, had stood for a considerably longer time, as did the samples of Thames water from Hampton analysed by us on this and a former occasion. We believe that this mode of water purification has not before been noticed; it is, however, deserving the attention of the water engineer, and its importance is increased by the fact that the precipitated organic matter is highly nitrogenised, the proportion of nitrogen to carbon in the organic matter removed being 1·5 : 1 in the above experiment.

In conclusion, we give the following table, illustrating the difference in the composition of filtered Thames water at Staines and Hampton in spring and autumn.

Names of Substances found.	Sources of Samples.			
	Thames Water just below the Weir at Staines.		Thames Water at Hampton.	
	May 2d.	Oct. 28th.	May 4th.	Oct. 28th.
Total solid residue from 100,000 parts of water evaporated and dried at 100° C.	31·20	31·40	27·87	29·90
Mineral substances in 100,000 parts of each water:				
Ammonia	·000	·004	·000	·006
Nitrogen as nitrates and nitrites	·215	·173	·196	·205
Organic substances in 100,000 parts of each water:				
Organic nitrogen	·027	·097	·024	·057
„ carbon	·304	·304	·260	·263
Hardness in 100,000 parts of each water	20·8	22·0	20·0	21·6

It will be seen that the most important difference between the chemical condition of the Thames in autumn and in spring is that at the former season the soluble organic matter is more highly nitrogenised. This difference is seen from the following comparison:—

	Staines.		Hampton.	
	Spring.	Autumn.	Spring.	Autumn.
Proportion of organic nitrogen to organic carbon	1 : 11·2	1 : 3·13	1 : 10·8	1 : 4·61

We have the honour to be, &c.

E. Frankland.
William Odling.

Royal College of Chemistry,
December 22, 1868.

APPENDIX BF.

Letter from the Engineer of the New River Company in explanation of his Answer to Question 3999.

New River Office, E.C.,
31st July 1868.

Dear Sir,

In reply to yours of the 29th instant, I have to explain that the amount returned as the aggregate yield of the New River Company's sources was made out thus:—

	Gallons.	
Average flow of the Chadwell spring	3,500,000	per diem.
Quantity which the New River Company are authorized to take, at all times, from the river Lea through their gauge at Hertford	22,500,000	„
Additional supplies from gathering ground at Cheshunt, &c.	500,000	„
Obtainable from six existing deep chalk wells, more than	8,000,000	„
Water collected in ponds at Hampstead and Highgate, and distributed through separate mains for watering roads, and other *non-domestic* purposes	500,000	„
	35,000,000	„

You will thus see that whatever supply may be obtained—

1. From a *new well* now in preparation at Wormley.
2. By pumping from the *Thames* through separate mains, for street and other such uses, or
3. By store of floods in Lea, or Thames, will be over and above the aforesaid 35,000,000 gallons.

I remain, &c.
James Muir.

William Pole, Esq., F.R.S.

APPENDIX BG.

Extracts from Report on the Chemical Quality of the Supply of Water to the Metropolis, by A. W. Hofmann, Professor of Chemistry in the Metropolitan School of Science, and Chemist to the Museum of Practical Geology, F.R.S., Ph.D., LL.D., &c., and Lindsey Blyth, Esq., Lecturer on Natural Philosophy at St. Mary's Hospital.

(This Report was made in 1856 to the Right Hon. William Cowper, M.P., President of the General Board of Health, together with an Engineering Report on the Works of the Companies, as altered under the provision of the Metropolis Water Act, 1852.)

The object of the inquiry being to obtain a view of the value of the waters in a sanitary respect and for domestic purposes, it was thought advisable to exclude from the investigation all details which did not directly affect this question.

In accordance with your instructions we have therefore confined ourselves in the analyses to:—

I. The determination of the hardness of the waters, *a.*, before boiling (permanent plus temporary hardness), and *b.*, after boiling (permanent hardness).

II. The determination of the total amount of solid matter contained in the waters.

III. The determination of the organic matter contained in the waters.

It was, moreover, considered important to repeat these determinations from time to time, so as to obtain some insight into the variations of the waters during the several seasons.

Of the above three determinations, the examination of the organic matter which is present in waters is of an especial interest in a sanitary point of view. This examination is attended with very considerable difficulties. The accurate determination of the quantity of organic matter in a water is one of the most delicate operations in analytical chemistry. Still greater is the difficulty of examining into

the nature of the organic matter; the total amount of organic matter is so small that immense quantities of water must be evaporated in order to obtain the material upon which to work, and few indeed are the data upon which a satisfactory examination of this kind can be founded at the present moment.

Very little is known of the nature of the ill-defined substances which constitute the organic matter generally found in water. Berzelius distinguishes two substances, crenic and apocrenic acids, which slightly differ in their chemical deportment; but these two bodies are as yet scarcely chemically examined, and much doubt still hangs over their individuality and even over their existence. The organic matter in water has been divided into *nitrogenous* and *non-nitrogenous* matter; but all we know is, that certain varieties of the organic matter found in water contain nitrogen, which is readily shown by treating them with hydrate of potash, when abundance of ammonia is evolved.

The opinions of chemists are divided as to the manner in which organic matter in water is capable, under certain conditions, of producing a deleterious effect upon the animal economy. But it is now generally admitted, that the substances which constitute the organic matter of water act injuriously by no means in consequence of being poisonous themselves, but by undergoing those great processes of transformation, called decay and putrefaction, to which all vegetable and animal matter is subject, when no longer under the control of vitality, either in plants or animals. These putrefactive processes either give rise to the formation of poisonous bodies, or they act simply as ferments, generating similar processes of decomposition in the substances composing the animal organism. Now, with special reference to the last mode of action, it is well established by general experience that *nitrogenous* substances are infinitely more liable to undergo putrefaction than organic bodies from which nitrogen is absent. And hence the very general and correct opinion that the deleterious character of organic matter in water is proportionate to the amount of *nitrogen* which it contains. Could this nitrogen be estimated with any degree of accuracy, such an estimate would certainly afford the most satisfactory element in the examination of the organic matter. Unfortunately this estimate is attended with very considerable difficulties. The nitrogen of the organic matter which has undergone putrefaction, and has therefore ceased to be deleterious, remains in the water, partly as ammonia, partly as nitric acid. It would therefore by no means be sufficient to evaporate the water and to determine the amount of nitrogen in the residue. It would be absolutely necessary to estimate also the nitrogen present in the form of nitric acid and of ammonia, and only after the deduction of their joint amount from the total amount, numbers would be obtained, which, representing the quantity of still putrescible nitrogenous substances, would afford, within certain limits, the necessary data for a comparison of the organic matter present in different waters.

It is obvious that this mode of proceeding is very complicated, and not likely to furnish trustworthy results, unless carried out with the greatest circumspection, and with all the appliances which the modern progress of analytical chemistry can suggest. It was our intention to enter fully into this part of the inquiry, and a series of experiments were actually made by us with the view of fixing on the best method of conducting the inquiry. The illness of Mr. Blyth, which at this period deprived us of his assistance, has compelled us to abandon, for the present at least, this part of the examinations, and to confine ourselves to an accurate determination of the hardness (permanent and temporary), of the total amount of solid constituents, and of the organic matter.

Collection of the Waters.

* * * *

The first series of samples were taken at your desire from the mains of each company, as near as possible to the houses supplied, so as to insure a fair estimate of the actual quality of the water used by the inhabitants of the metropolis.

* * * *

The exact source of each sample, and the date of taking it, are stated in the tables giving the result of the examination.

In the second series of samples, taken at a later period of the year, it was desired to obtain some information as to the effects of filtration. To this end, samples were taken of the waters before and after filtration at the works of each company, and with the co-operation of their officers, as well as from the mains within the district supplied. As in the first instance, the source of the waters and the date of taking them are stated in the tables.

* * * *

Chemical Examination of the Water.

The following tables exhibit the results obtained in the analysis of the ten waters submitted to examination. It may be stated that each number contained in the table is, with one or two exceptions, the mean of two well concordant experiments, the details of which are united in the Appendix. The hardness was determined by the well-known elegant process of Professor Clark; the second determination (of the permanent hardness) being made after five minutes boiling. This deserves particularly to be mentioned, inasmuch as by protracted ebullition the hardness may be still further reduced. The total amount of solid constituents was determined by evaporating an exactly measured quantity of the water with a known amount of carbonate of soda in platinum capsules, and weighing the residue, dried at a temperature of 248° F., in the same capsules. This residue ignited, and subsequently moistened repeatedly with solution of carbonate of ammonia (to replace the carbonic acid which lime and magnesia salts might have lost during the ignition), and dried at a gentle heat until the weight had become constant, furnished the amount of saline, and, by calculation, the amount of organic matter.

For the sake of comparison we have added in each case the results obtained, in 1851, by the Government Commission (consisting of Professors Graham, Miller, and Hofmann).

I.—Water supplied to the Metropolis by the Grand Junction Water Company.

Results obtained in 1856.

Description of Water.	Date of taking.	Hardness.			Solid Constituents, Grains per Gallon.		
		Total.	Permanent.	Temporary.	Total Solid Residue.	Organic Matter	Inorganic Matter
From main in Grand Junction Road; filtered.	Jan. 18	15·95	9·05	6·90	23·35	1·98	21·37
From stand pipe in Piccadilly; filtered.	Mar. 29	14·10	6·50	7·60	21·21	1·015	20·195
From pipe at works coming from Hampton; unfiltered.	Mar. 29	14·55	8·2	6·35	23·22	1·17	22·05

Results obtained by the Government Commission in 1851.

Nearest accessible point to the works of the Company.	Between Jan. 29 and 31.	14·00	—	—	21·72	3·07	18·65

II.—Water supplied to the Metropolis by the West Middlesex Water Company.

Results obtained in 1856.

Description of Water.	Date of taking.	Hardness.			Solid Constituents, Grains per Gallon.		
		Total.	Permanent.	Temporary.	Total Solid Residue.	Organic Matter	Inorganic Matter
Service pipe near Dorset Square; filtered.	Jan. 18	13·65	9·4	4·25	21·16	0·819	20·341
From cab-stand, Broadway, Hammersmith; filtered.	Mar. 31	14·4	7·4	7·0	19·897	1·015	18·882
From Hampton; unfiltered.	Mar. 31	14·8	7·55	7·25	22·05	1·05	21·00

Results obtained by the Government Commission in 1851.

Nearest accessible point to the works of the Company.	Between Jan. 29 and 31.	14·6	—	—	22·67	2·75	19·92

III.—Water supplied to the Metropolis by the Chelsea Water Company.*

Results obtained in 1856.

Description of Water.	Date of taking.	Hardness.			Solid Constituents, Grains per Gallon.		
		Total.	Permanent.	Temporary.	Total Solid Residue.	Organic Matter	Inorganic Matter
From stand pipe at cab-stand in King Street; filtered.	Jan. 22	11·8	9·05	2·75	20·31	Lost.	Lost.
From stand pipe at cab-stand, King Street; filtered.	April 2	14·8	8·25	6·55	23·397	1·207	22·19
From works at Thames Bank; unfiltered.	April 2	14·8	8·6	6·2	24·675	1·645	23·03

Results obtained by the Government Commission in 1851.

Nearest accessible point to the works of the Company.	Between Jan. 29 and 31.	14·44	—	—	21·28	2·38	18·90

* Since these samples were taken, the Chelsea Water Company have altered the source of their supply. They now obtain their water at Thames Ditton, but samples from the new source had not been examined when this report was completed.

IV.—Water supplied to the Metropolis by the Southwark and Vauxhall Water Company.

Results obtained in 1856.

Description of Water.	Date of taking.	Hardness.			Solid Constituents, Grains per Gallon.		
		Total.	Permanent.	Temporary.	Total Solid Residue.	Organic Matter	Inorganic Matter
From cab-stand near Church in Kennington Common; filtered.	Jan. 23	12·02	7·75	4·27	20·57	1·36	19·21
From main at Kennington Church; filtered.	Mar. 27	14·5	9·85	4·65	21·105	1·33	19·775
From pipe from Hampton Works; unfiltered.	Mar. 27	14·25	7·07	7·18	21·927	1·435	20·49

Results obtained by the Government Commission in 1851.

Nearest accessible point to the works of the Company.	Between Jan. 29 and 31.	15·00	—	—	21·08	1·51	19·27

V.—Water supplied to the Metropolis by the Lambeth Water Company.

Results obtained in 1856.

Description of Water.	Date of taking.	Hardness.			Solid Constituents, Grains per Gallon.		
		Total.	Permanent.	Temporary.	Total Solid Residue.	Organic Matter	Inorganic Matter
From stand pipe at cab-stand, Manor Place, Walworth Road; filtered.	Jan. 23	11·35	8·10	3·25	19·11	1·26	17·85
From stand pipe, Borough Road; filtered.	April 5	12·05	7·6	4·45	20·195	0·80	19·325
From south side of the River at Thames Ditton; unfiltered.	April 11	10·90	8·45	2·45	30·10	3·91	26·18
From north side of the River at Thames Ditton; unfiltered.	April 11	12·55	7·75	4·80	20·205	1·925	18·28

Results obtained by the Government Commission in 1851.

Nearest accessible point to the works of the Company.	Between Jan. 29 and 31.	14·16	—	—	20·40	2·59	17·81

VI.—Water supplied to the Metropolis by the New River Water Company.

Results obtained in 1856.

Description of Water.	Date of taking.	Hardness.			Solid Constituents, Grains per Gallon.		
		Total.	Permanent.	Temporary.	Total Solid Residue.	Organic Matter	Inorganic Matter
From stand pipe at cab-stand, Agar Street, Strand; filtered.	Jan. 25	14·6	7·75	6·85	22·36	0·910	21·45
From Agar Street, Strand; filtered.	April 4	12·6	9·25	3·36	21·07	1·015	20·055
From works; unfiltered.	April 4	13·1	6·5	9·9	21·91	0·98	20·93

Results obtained by the Government Commission in 1851.

Nearest accessible point of the works of the Company.	Between Jan. 29 and 31.	14·9	—	—	19·50	2·79	16·71

VII.—Water supplied to the Metropolis by the East London Water Company.

Results obtained in 1856.

Description of Water.	Date of taking.	Hardness.			Solid Constituents, Grains per Gallon.		
		Total.	Permanent.	Temporary.	Total Solid Residue.	Organic Matter	Inorganic Matter
From stand pipe at cottages near Bow Common; filtered.	Jan. 22	13·98	8·05	5·93	22·17	1·28	20·89
From service pipe at inspector's office; filtered.	April 1	14·65	8·25	6·40	20·685	1·00	19·365
From works at Lea Bridge; unfiltered.	April 1	13·3	6·3	7·0	23·31	0·945	22·365

Results obtained by the Government Commission in 1851.

Nearest accessible point to the works of the Company.	Between Jan. 29 and 31	15·00	—	—	23·51	4·12	19·39

VIII.—Water supplied to the Metropolis by the Kent Water Company.

Results obtained in 1856.

Description of Water.	Date of taking.	Hardness.			Solid Constituents, Grains per Gallon.		
		Total.	Permanent.	Temporary.	Total Solid Residue.	Organic Matter	Inorganic Matter
From service pipe, New Cross; filtered.	Jan. 23	12·45	12·3	0·15	28·49	1·26	27·23
From well at works, as being pumped into mains; filtered.	April 5	11·1	9·3	1·8	23·87	1·19	22·68
From subsiding reservoir, at works, Deptford; unfiltered.	April 5	12·55	8·70	3·85	27·30	1·382	25·918

Results obtained by the Government Commission in 1851.

Nearest accessible point to the works of the Company.	Between Jan. 29 and 31.	16·0	—	—	29·71	2·61	27·10

IX.—Water supplied to the Metropolis by the Hampstead Water Company.

Results obtained in 1856.

Description of Water.	Date of taking.	Hardness.			Solid Constituents, Grains per Gallon.		
		Total.	Permanent.	Temporary.	Total Solid Residue.	Organic Matter	Inorganic Matter
From service pipe at cottages, Highgate Hill; mixed.	Jan. 22	10·5	10·5	0·0	34·26	1·29	32·97
From service pipe; mixed.	April 4	5·45	5·40	0·05	30·765	1·47	29·295
From well at Hampstead; unfiltered.	April 4	4·7	3·9	0·8	57·101	2·24	54·861
From the works at Highgate; unfiltered.	April 4	6·35	6·35	0·0	22·54	1·575	20·965

Results obtained by the Government Commission in 1851.

Nearest accessible point to the works of the Company.	Between Jan. 29 and 31.	9·8	—	—	35·41	1·81	33·57

X.—Water supplied to Woolwich by the Woolwich and Plumstead Water Company.

Results obtained in 1856.

Description of Water.	Date of taking.	Hardness.			Solid Constituents, Grains per Gallon.		
		Total.	Permanent.	Temporary.	Total Solid Residue.	Organic Matter	Inorganic Matter
From works at Plumstead; softened.	Jan. 25	8·15	8·1	0·05	18·84	0·75	18·09
From service tap at the cottages near the railway station, Woolwich Arsenal.	April 5	12·85	10·05	2·80	21 85	1·015	23·835
From well at works; unsoftened.	April 5	22·65	10·25	12·40	33·163	1·05	32·113

The analytical results tabulated in the preceding pages demand but little interpretation. The number of analytical determinations, although considerable, is not sufficient to furnish the data which are necessary for the elaboration of a definite view regarding the fluctuations in the composition of the waters supplied to the metropolis at different seasons. In fact, the elements which are capable of influencing the composition of the waters are so manifold and liable to such extraordinary variations, that it becomes obvious that the number of estimations has still to be considerably increased. Then only will it be possible to eliminate the influence of accidental disturbances upon the general features of the analysis. It would therefore be premature to enter into a comparative discussion of the results obtained in January and in April, and of the slight discrepancies exhibited by the analyses of the waters of the same company taken at different localities and under circumstances otherwise different.

A most interesting fact, however, is elicited, if the average result obtained in 1856 be compared with the results of the analyses made in 1851 by the Government Commission.

In the following table these results are placed in juxtaposition:—

Comparison of the Average Results obtained in the Analysis of 1856 *with those of the Analysis made in* 1851.

Description of Water.	Date of taking.	Hardness.			Solid Constituents, Grains per Gallon.		
		Total.	Permanent.	Temporary.	Total Solid Residue.	Organic Matter	Inorganic Matter
Grand Junction Water Company.	1851	14·00	—	—	21·72	3·07	18·65
	1856	14·87	7·92	6·95	22·59	1·38	21·21
West Middlesex Water Company.	1851	14·60	—	—	22·67	2·75	19·92
	1856	14·28	8·12	6·16	21·03	0·96	20·07
Chelsea Water Company.	1851	14·44	—	—	21·28	2·38	18·90
	1856	13·80	8·63	5·17	22·79	1·42	21·37
Southwark and Vauxhall Water Company.	1851	15·00	—	—	21·08	1·51	19·57
	1856	13·59	8·22	5·37	21·19	1·37	19·82
Lambeth Water Company.	1851	14·16	—	—	20·40	2·59	17·81
	1856	11·98	7·82	4·16	19·84	1·33	18·51
New River Water Company.	1851	14·9	—	—	19·50	2·79	16·71
	1856	13·4	7·8	5·6	21·78	0·968	20·812
East London Water Company.	1851	15·00	—	—	23·51	4·12	19·39
	1856	13·98	7·53	6·45	22·05	1·09	20·96
Kent Water Company.	1851	16·00	—	—	29·71	2·61	27·10
	1856	12·03	10·1	1·93	26·10	1·37	24·73
Hampstead Water Company.	1851	9·8	—	—	35·41	1·84	33·57
	1856	7·43	7·41	0·02	29·19	1·45	27·74

This table shows that the hardness of the waters in 1856 was, with one exception, somewhat less than in 1851; the diminution, however, with one or two exceptions, is only trifling. The total amount of solid matter in the two years likewise exhibits but unimportant fluctuations.

A very considerable diminution, however, is observed in the amount of organic matter.

In fact, in 1856 the waters supplied to the metropolis contained not more than one-half of the organic matter which was present in the year 1851.

This result is certainly not accidental. The diminution is not merely an average result, but uniformly observed throughout. The waters examined in 1851 were taken in January; those investigated in 1856, partly in January and partly in April. The diminution of the organic matter cannot therefore be due to the influence of the season. Nor can it be due to any difference in the mode of determining the organic matter in 1851 and 1856. These determinations were made by exactly the same method; for it so happens that the analytical part of the inquiry in 1851 which refers to the organic matter was likewise made in the laboratory of the Royal College of Chemistry. The diminution is obviously partly due to the alteration of the localities from which many of the companies derive their supply. The Grand Junction, the West Middlesex, the Southwark and Vauxhall companies, formerly supplied respectively at Kew, Barnes, and Battersea, derive their present water from Hampton; the Lambeth Water Company used to take their water at Lambeth, but have now erected extensive works at Thames Ditton. The diminution of the organic matter in the London water supply is, however, by no means confined to the companies that have changed the locality of their source, and it must therefore be attributed in a great degree to the considerable improvement which has taken place in the collection, filtration and general management of the supply of water to the metropolis.

A. W. Hofmann, F.R.S.
Lindsey Blyth.

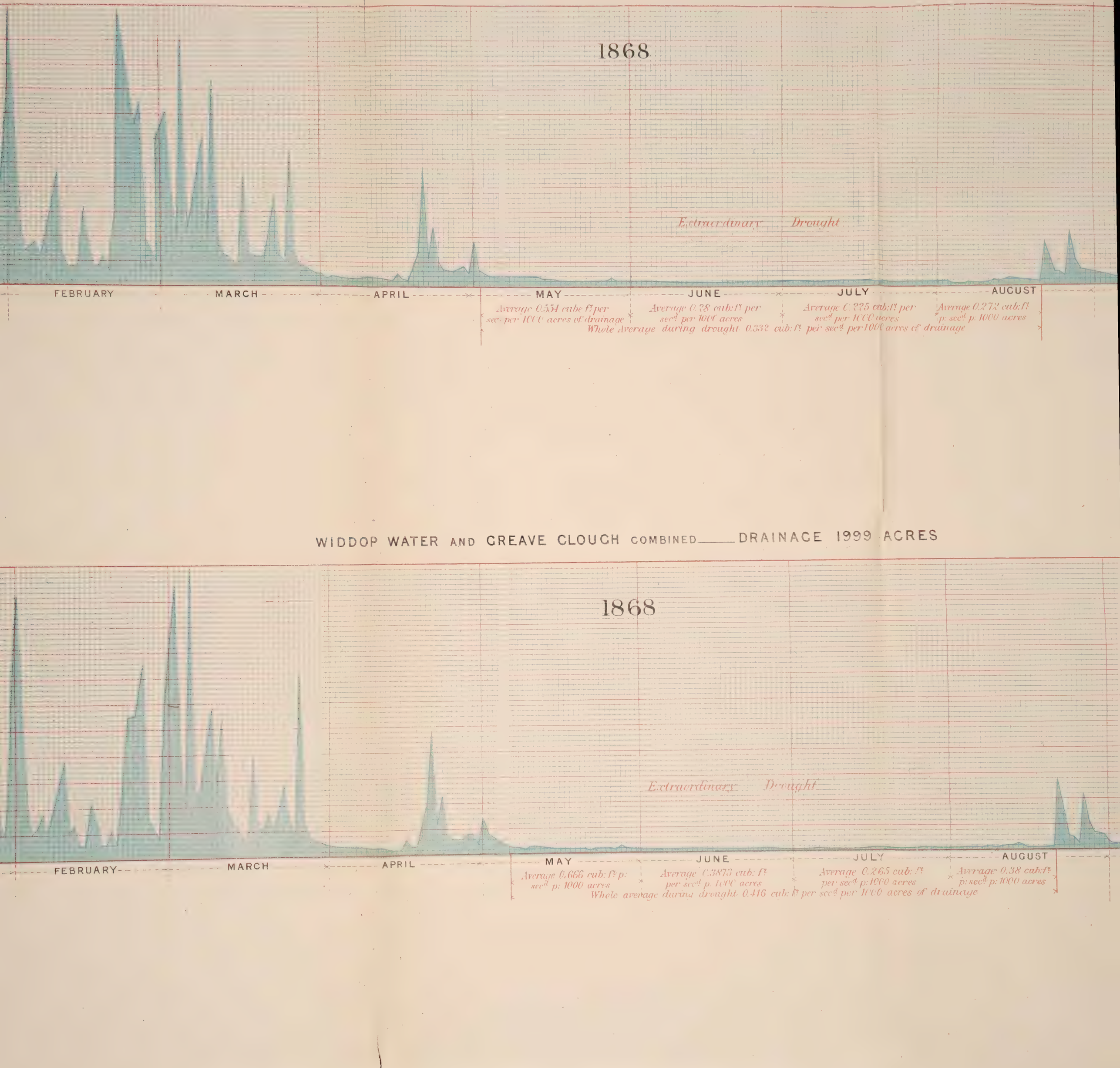
ROYAL COMMISSION ON WATER SUPPLY.

HALIFAX CORPORATION WATER WORKS. EXTENSIONS.

DIAGRAM SHOWING THE FLOW OF THE WATER.

Prepared by Mr Bateman.

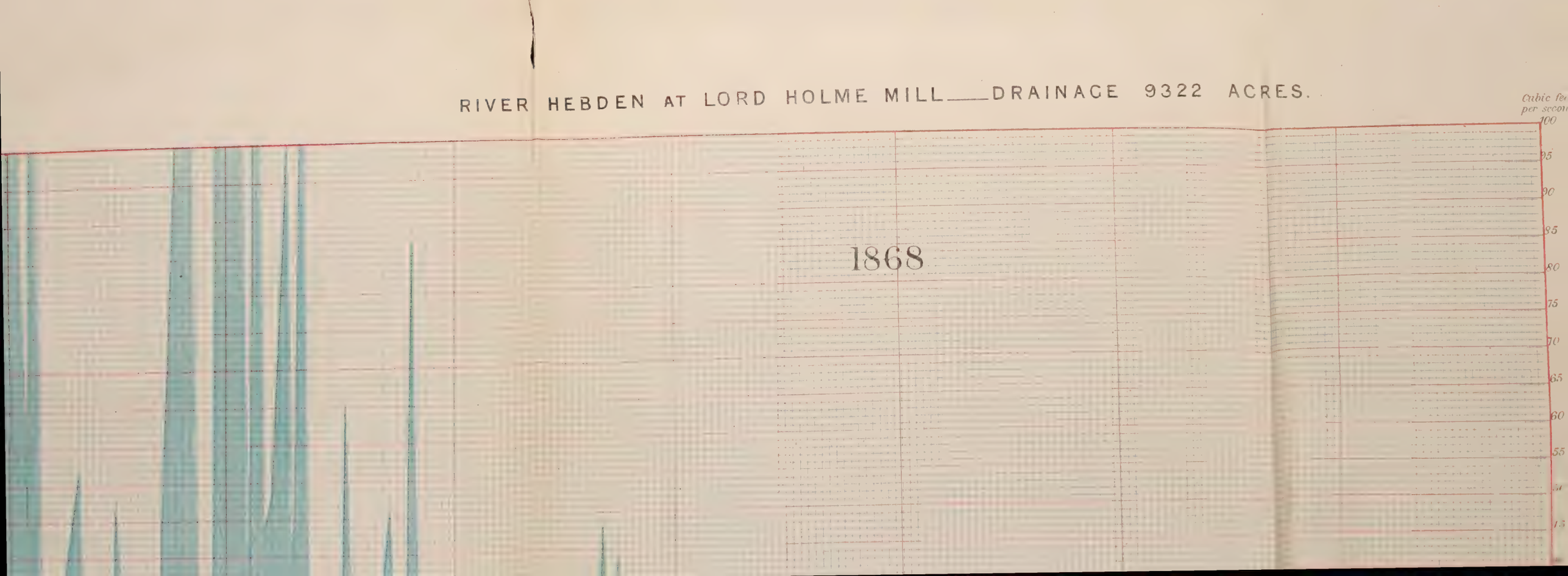
WALSHAW DEAN WATER.—DRAINAGE 2325 ACRES.


1868
Extraordinary Drought
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
Average 0.554 cube ft per sec. per 1000 acres of drainage
Average 0.28 cub: ft per sec^d per 1000 acres
Average 0.225 cub: ft per sec^d per 1000 acres
Average 0.272 cub: ft p: sec^d p: 1000 acres
Whole Average during drought 0.332 cub: ft per sec^d per 1000 acres of drainage

WIDDOP WATER AND GREAVE CLOUGH COMBINED—DRAINAGE 1999 ACRES

1868
Extraordinary Drought
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
Average 0.666 cub: ft p: sec^d p: 1000 acres
Average 0.3875 cub: ft per sec^d p. 1000 acres
Average 0.265 cub: ft per sec^d p: 1000 acres
Average 0.38 cub: ft p: sec^d p: 1000 acres
Whole average during drought 0.416 cub: ft per sec^d per 1000 acres of drainage

RIVER HEBDEN AT LORD HOLME MILL—DRAINAGE 9322 ACRES.



APPENDIX BJ.

INFORMATION from Mr. TAUNTON as to GAUGINGS of the THAMES at LECHLADE, and other data affecting the Upper Basin of the Thames.

Brimscombe Port, Stroud,
January 30, 1869.

DEAR SIR,

IN reply to yours of the 21st instant, I have now the pleasure to send you enclosures marked A, the gaugings of the Thames at St. John's Lock, as made by me in October and November 1867, during a short-water period. I append copy of the Rain Gauge Returns (enclosure marked B) kept at Thames Head from 1859 to 1869, and you will observe that whilst the average quantity of rain that fell within that period has been for October 2·77 inches, and November 2·19 inches, it was in 1867 1·99 inches for October, and ·98 inches for November. You will notice also that the rainfall at Thames Head of 1867 was about two inches below the average. The gaugings were therefore taken at a proper period, which I selected when I had the means of putting stop planks across the head of the lock at St. John's, Lechlade, and you may depend upon them.

I send enclosure marked C, a return as to the summit level of the Thames and Severn Canal from 1863 to 1865, both inclusive (which was prepared for a Parliamentary inquiry in 866), that may be of service to your Commission. It gives the quantity of water pumped weekly at Thames Head into the navigation and the lockage, eastwards and westwards, that is, towards the Thames and the Severn respectively.

I also forward enclosure marked D, a section along the Stroud water and Thames and Severn Canal between these two rivers. (See Appendix B K.)

In reference to the Cotteswold district, the large volume of the springs with which it abounds, such as those at Bibury, Syreford, Foss Bridge, South Cerney, Chalford Thames Head, &c., yielding some of them as much as 3,000,000 gallons each per diem, quite characterizes that district, and distinguishes it from those localities where the waters mainly pass off down surface channels, and where reservoirs must be formed for the storeage and utilization of such waters.

Here the storeage is already effected by nature in subterranean reservoirs, being the cavities in the loose rocks of the inferior or great oolites, into which the rain so freely permeates that floods and surface torrents are here unknown. The bottom of these reservoirs in the inferior oolite is the upper lias clays, and in the great oolite the fuller's earth bed forms the impervious floor.

The springs to which I have referred are outlets from these reservoirs.

But it happens that the spring waters, after coming to the surface, are sometimes lost again in the loose ground traversed by their surface channels, and that much water due to the valley of the Thames is lost from it.

First. My idea is to get back this or some large portion of it.

Secondly. That if a supplemental supply brought from a long distance is required for London, a separate service of the purest spring water sufficient for the whole of the inhabitants of London for drinking and culinary purposes may be obtained from the Cotteswolds, and conveyed throughout in covered conduits.

Thirdly. The waterclosets being the great consumers of water, it seems to me there are adequate sources of supply for them, as well as for domestic, manufacturing, and general purposes at present.

I have repeated these remarks, contained in mine to you of the 13th March 1868, as I have not had the opportunity of giving them in evidence before your Commission.

Believe me, yours faithfully,
JOHN H. TAUNTON.

W. Pole, Esq.

ENCLOSURE A.—A TABLE of the GAUGINGS of the THAMES at LECHLADE, St. John's Lock, by Overfall 15 feet wide, and of RAINFALL at BRIMSCOMBE and THAMES HEAD, during October and November 1867.

Date, 1867.	Time of Gauging.	Depth of Overfall.	Cubic Feet per Minute.	Gallons per Diem.	Rainfall at Brimscombe.	Rainfall at Thames Head.*
		Inches.			Inches.	Inches.
Oct. 1	—	—	—	—	—	—
„ 2	—	—	—	—	—	—
„ 3	—	—	—	—	·13	—
„ 4	—	—	—	—	—	—
„ 5	—	—	—	—	—	—
„ 6	—	—	—	—	·14	—
„ 7	—	—	—	—	·09	—
„ 8	—	—	—	—	·32	—
„ 9	—	—	—	—	·20	·77
„ 10	—	—	—	—	—	—
„ 11	—	—	—	—	—	—
„ 12	—	—	—	—	·18	·37
„ 13	—	—	—	—	—	—
„ 14	—	—	—	—	·00	—
„ 15	—	—	—	—	·03	—
„ 16	—	—	—	—	·11	—
„ 17	—	—	—	—	·27	·47
„ 18	10.30 a.m.	11				
„ „	1.30 p.m.	11¼	2,900	26,024,832	—	—
„ „	4.30 p.m.	11⅜				
„ 19	Morning	12⅛				
„ „	Evening	12	3,540	31,822,081	—	·28
„ 20	Morning	14⅝				
„ „	Evening	14¼	5,215	46,709,826	—	—
„ 21	Morning	12¼				
„ „	Evening	12⅜	3,700	33,204,096	·19	—
„ 22	Morning	11½				
„ „	Evening	11⅛	2,930	26,204,052	—	·15
„ 23	Morning	11⅛				
„ „	Evening	11½	3,040	27,281,200	—	—
„ 24	Morning	11¼				
„ „	Evening	10½	2,870	25,755,604	—	—
„ 25	Morning	11⅛				
„ „	Evening	10⅜	2,790	25,037,676	—	—
„ 26	Morning	10⅜				
„ „	Evening	10⅛	2,645	23,736,438	—	—
„ 27	Morning	9	2,295	20,595,506	—	—
„ 28	Morning	9⅛				
„ „	Evening	9⅜	2,456	22,040,336	·29	—
„ 29	Morning	12¾				
„ „	Evening	14	4,515	40,517,970	·07	—
„ 30	—	—	—	—	·12	—
„ 31	—	—	—	—	·03	—
Totals					2·28	1·99
Averages			3,242	29,092,468	—	—
Nov. 1	—	—	—	—	·10	—
„ 2	—	—	—	—	—	·54
„ 3	—	—	—	—	—	·25
„ 4	—	—	—	—	—	—
„ 5	—	—	—	—	—	—
„ 6	—	—	—	—	—	—
„ 7	—	—	—	—	—	—
„ 8	—	—	—	—	—	—
„ 9	—	—	—	—	—	—
„ 10	—	—	—	—	—	—
„ 11	—	—	—	—	—	—
„ 12	—	—	—	—	—	—
„ 13	—	—	—	—	—	—
„ 14	—	—	—	—	·26	—
„ 15	—	—	—	—	·24	·08
„ 16	—	—	—	—	—	—
„ 17	—	—	—	—	—	—
„ 18	—	—	—	—	—	—
„ 19	—	—	—	—	—	—
„ 20	—	—	—	—	—	—
„ 21	—	—	—	—	—	—
„ 22	Evening	8½	1,800	16,153,344*	—	—
„ 23	Morning	9⅛				
„ „	Evening	8	1,935	17,364,842	—	—
„ 24	Morning	9⅛				
„ „	Evening	9	2,167	19,446,826	—	—
„ 25	Morning	7				
„ „	Evening	7¼	1,470	13,191,892†	—	—
„ 26	Morning	8				
„ „	Evening	7⅞	1,650	14,807,228	—	·01
„ 27	Morning	8⅝				
„ „	Evening	9	2,032	18,235,328†	—	·04
„ 28	Morning	9⅛				
„ „	Evening	8⅛	2,032	18,235,328	—	—
„ 29	Morning	8				
„ „	Evening	8⅛	1,785	16,018,726	—	—
„ 30	Morning	8⅛				
„ „	Evening	9⅛	2,083	18,693,002	·05	—
Dec. 1	Morning	12⅛	3,402	30,529,820‡	—	—
Totals					·65	·98
Averages			2,035	18,267,693	—	—
Estimated leakage at St. John's Weir, measured and included in October gaugings			100	897,408	—	—
			2,135	19,165,041	—	—

* The rain observations at Thames Head were not returned daily.

* The stop planks having been removed were refixed this day.
† Mills on the Colne above not at work.
‡ Sunday, and heavy rain commences.

Thames and Severn Canal Navigation—Abstract of Weekly Returns, &c.—*continued.*

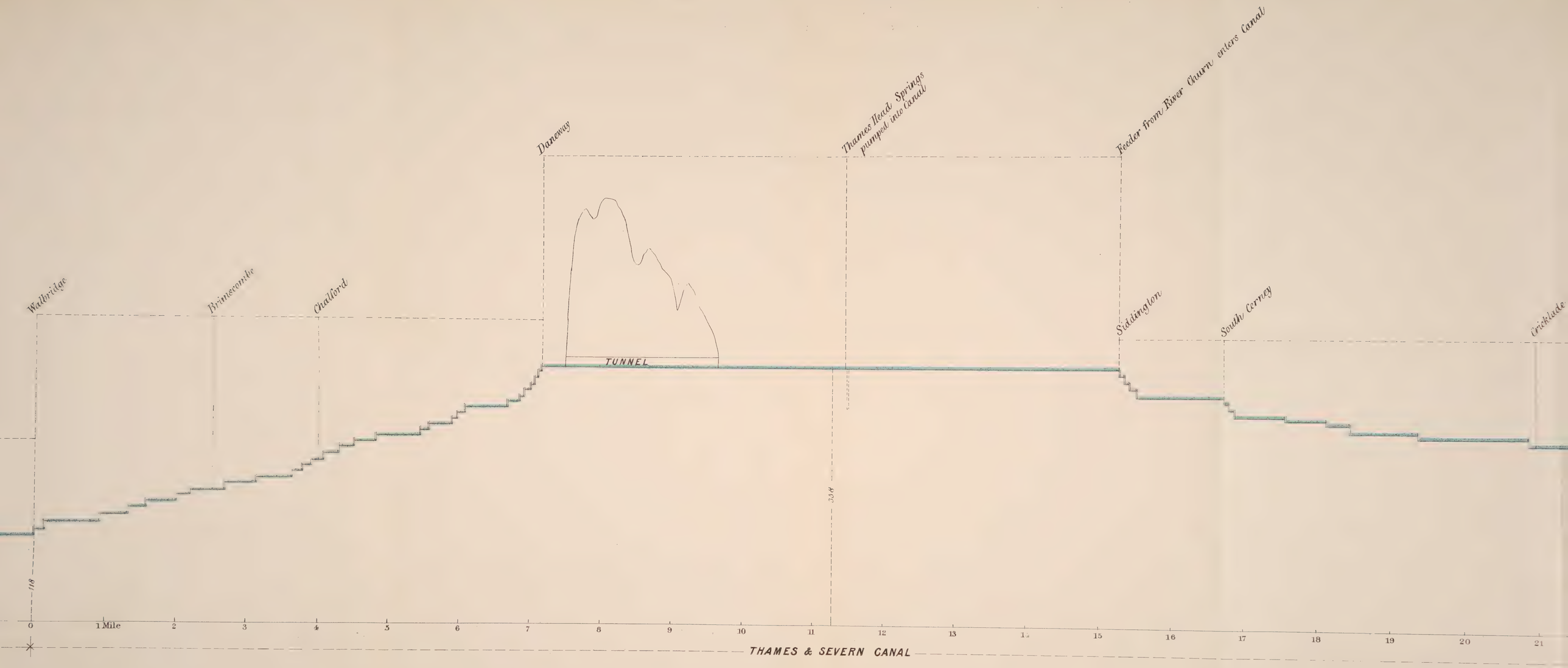
1865.

Date.	Depth of Water on Cill at Daneway.	Monthly Rainfall.	Water pumped into Summit at Thames Head.	Lockage Eastwards.		Lockage Westwards.		Remarks.
				Gross.	Reduced for Leakage at Gates, Paddles, &c.	Reduced for Leakage at Gates, Paddles, &c.	Gross.	
	ft. ins.		Gallons.	Locks.			Locks.	
Jan. 7	3 2	—	20,160,000	37	16	10	31	
„ 14	3 2	—	20,160,000	45	24	20	41	
„ 21	3 4½	—	20,160,000	79	58	31	52	
„ 28	3 5	2·41	20,160,000	29	8	9	30	
Feb. 4	4 2½	—	16,920,000	—	—	—	—	No return from Superintendent at east end; lock-keeper's return from west end, 25 locks.
„ 11	4 1½	—	—	—	—	—	—	Ditto ditto ditto 13 locks.
„ 18	4 0½	—	—	25	4	24	45	
„ 25	4 0	2·17	—	35	14	31	52	
Mar. 4	4 2½	—	—	45	24	39	60	
„ 11	3 11	—	—	49	28	25	46	
„ 18	3 9	—	—	57	36	26	47	
„ 25	3 6	1·11	5,040,000	53	32	44	65	
Apr. 1	3 6	—	17,400,000	41	20	37	58	
„ 8	3 4	—	17,280,000	51	30	25	46	
„ 15	3 3½	—	19,320,000	39	18	28	49	
„ 22	3 4	—	20,160,000	45	24	64	85	
„ 29	3 4	1·09	20,160,000	51	30	59	80	
May 6	—	—	20,160,000	—	—	—	—	Stoppage of canal for repairs; return from Superintendent at east end, 33 locks.
„ 13	3 3½	—	20,160,000	—	—	—	—	Ditto ditto ditto 30 locks.
„ 20	3 1	—	20,160,000	70	49	51	72	
„ 27	3 0	1·86	20,160,000	50	29	64	85	
June 3	3 0	—	20,160,000	51	30	36	57	
„ 10	3 0	—	20,160,000	43	22	33	54	
„ 17	2 11½	—	20,160,000	59	38	61	82	
„ 24	2 9	0·97	20,160,000	57	36	27	48	
July 1	2 8½	—	20,160,000	71	50	63	84	
„ 8	2 8½	—	13,560,000	71	50	61	82	
„ 15	2 11½	—	19,740,000	47	26	22	43	
„ 22	2 11½	—	20,160,000	71	50	27	48	
„ 29	2 10½	4·90	20,160,000	65	44	28	49	
Aug. 5	2 8½	—	19,200,000	—	—	—	—	No return from Superintendent at east end; lock-keeper's return from west end, 18 locks.
„ 12	2 10	—	20,160,000	59	38	34	55	
„ 19	2 9	—	18,960,000	37	16	22	43	
„ 26	3 0	3·93	20,160,000	45	24	26	47	
Sept. 2	3 1	—	20,160,000	45	24	28	49	
„ 9	2 11	—	20,160,000	58	37	27	48	
„ 16	2 8½	—	20,160,000	58	37	32	53	
„ 23	3 0	—	19,200,000	41	20	21	42	
„ 30	3 1	—	20,160,000	53	32	31	52	
Oct. 7	3 2	—	20,160,000	—	—	—	—	No return from Superintendent at east end; lock-keeper's return from west end, 28 locks.
„ 14	3 2	—	20,160,000	53	32	21	42	
„ 21	3 3	—	20,160,000	61	40	41	62	
„ 28	3 3	5·24	20,160,000	—	—	—	—	No return from Superintendent at east end; lock-keeper's return from west end, 28 locks.
Nov. 4	3 7	—	20,160,000	—	—	—	—	Ditto ditto ditto 26 locks.
„ 11	3 4	0·24	20,160,000	45	24	31	52	
Total - -		23·92	751,260,000	1,891	1,114	1,259	2,036	
Average - -		—	19,263,076	51	30	34	55	

SECTION OF THE THAMES & SEVERN AND STROUDWATER CANAL.

COMMUNICATED BY Mr TAUNTON.

Enclosure D



HORIZONTAL SCALE, *One Inch to a Mile.*
VERTICAL SCALE, *100 Feet to an Inch.*

APPENDIX BL.

LETTERS on the DEFICIENT SUPPLY of WATER in case of FIRE in the BOROUGH of SOUTHWARK.

St. Saviour's District Board of Works,
Board Room, Emerson Street,
Bankside, Southwark, S.E.

DEAR SIR, Water Supply. December 11, 1868.

I AM directed by the St. Saviour's District Board of Works to forward to you, for your information, copies of a letter or memorial to the Board from hop factors having premises in the vicinity of the Borough, complaining of the inadequate supply of water, and of the letter of the Southwark and Vauxhall Water Company in reply thereto.

The Board have directed the forwarding of the same to you, thinking perhaps that you might deem it expedient to submit the same to the Committee on the Water Supply, of which you are a member.

I am, &c.

Sir John Thwaites. HERBERT STURMY, Clerk.

The St. Saviour's District Board of Works.

GENTLEMEN, Borough, October 27, 1868.

WE beg to draw your attention to the fact that the premiums of insurance from fire have since last Michaelmas been advanced 75 per cent. on all hop warehouses in the Borough, on the ground (as stated in the various renewal notices) of the wholly inadequate supply of water.

The manager of one of the leading city fire offices writes thus:—"The recent advance in the rate of premium for hop "warehouses in the Borough was only made after the "subject had been fully discussed by the associated offices, "and as *the water supply throughout the whole district is so "scanty as to be ineffectual for the prompt suppression of "any large fire, it was resolved,*" &c.

The manager of another writes thus:—

"It" (the advance) "is adopted by all the companies, "and would not have occurred but from the fact recently "ascertained of the *very inefficient supply of water in your "district when a fire arises.* The cause has been fully re- "ported on by competent persons, and the offices are "satisfied that unless the owners of property interested "agitate the question of the better means of supplying "water, they must protect themselves by asking such rates "as they think are adequate to the risk."

If this be the case *all* property in this district must be in at least equal danger should a fire break out, and it may spread widely if the supply of water is inadequate to extinguish it. We trust you will inquire into the subject, and if those statements be correct exercise your powers to make the water companies supply sufficient water for the protection of the property of your ratepayers.

Yours obediently,

T. PARKES & SON, 7, Counter Street.
S. H. MOUNTAIN, Red Cross Street, Boro'.
P. S. PUNNEK, for the Hop Planters' Company, Southwark Street.
EVANS & CO., 227, High Street.
WM. DUNK & SONS, 230, High Street.
WOOLOTON & SON, 246, High Street.
PATTENDEN & SMITH, 14, Southwark Street.
J. T. NOAKES, 4, Southwark Street.
W. COSIER & CO., 15, Three Crown Square, Boro'.
THOS. RICHARDSON & SON, 6, Duke Street, Southwark.

Southwark and Vauxhall Water Company,
Sumner Street, Southwark,

DEAR SIR, November 28, 1868.

I BEG to acknowledge the receipt of your letter of the 17th instant, enclosing copy of a memorial sent to the St. Saviour's Board of Works on the subject of short supply of water in case of fire to the hop warehouses, &c. in the Borough and its vicinity.

In reply, I am instructed to inform you that the short supply referred to arises from no fault of this company, but solely in consequence of the owners of the hop and other warehouses making no provision themselves to insure a proper supply. The company's pipes are laid throughout the district of sizes proportioned to the demand for water by their servants, and unless special fire-mains are laid by the owners of property, the supply of water for fire purposes can only be procured from the ordinary street service pipe, excepting in those where a leading main may happen to be laid.

So far as the company is concerned, it is evident that they could not afford an additional expenditure for fire-mains for which they would receive no remuneration whatever, as the supply of water for fires is in all cases afforded gratuitously. The company already loses heavily in consequence of many of the hop and other warehouses being built on sites formerly occupied by numbers of small houses, to supply which the pipes were originally laid, and for which a considerable revenue was receivable, whereas the supply taken at the hop warehouses seldom exceeds the quantity required for washing hands, &c., at a rate of from 21*s.* to 42*s.* per annum. In many cases no water whatever is laid on to the hop warehouses, and therefore no rate paid.

The company have always been desirous to assist by every means in their power the owners of property in making provisions against fire, and have offered, and still offer, to allow any fire-mains that may be laid to be connected with their leading mains, without any charge or rate whatever, but the owners of property have in very few instances availed themselves of this privilege.

I am, &c.
CHAS. ROBINSON, Secretary.

To Herbert Sturmy, Esq.,
St. Saviour's District Board of Works,
Emerson Street, Bankside, Southwark.

APPENDIX BM.

LETTERS from Mr. HASSARD and Mr. SYMONS, on the RAINFALL in the LAKE DISTRICT during the Drought of 1868.

1, Westminster Chambers, Victoria Street, S.W.,
December 15, 1868.

DEAR SIR,

IN order to set at rest the question of how far the drought of last summer would have affected our project for supplying the metropolis, &c. with water from the Lake district, I have, since receiving your last communication, applied to Mr. Symons to let me know what amount of rain fell there during the drought in other parts of the country.

You will see from his letter, which I enclose, that the average rainfall in that part of the Lake district constituting our gathering ground, was, for the months of April, May, June, July, and August, 23·09 inches, and, further, that our reservoirs would have been quite full at the commencement of the drought.

All the stations, excepting Seathwaite, in the table of rainfall given by Mr. Symons are within our collecting area, and in the average at foot of the table you will see that Seathwaite has been excluded.

Out of the 23·09 inches of rain which fell in the Lake district during the drought elsewhere, there would, from the steep and non-absorbent nature of the ground, have flowed into the reservoirs at least 15 inches; this quantity from the area of our gathering ground would amount to 154 days' supply of 250,000,000 gallons, so that during even this period of drought the supply would have rather

exceeded the demand, so far as regards towns supply, leaving the compensation water only, or about 80,000,000 gallons daily, to be drawn out of the reservoirs. The sufficiency of our project in this respect is therefore placed beyond dispute or doubt.

Will you have the kindness to lay this communication and Mr. Symons' letter accompanying it before the next meeting of the Commission, and oblige

Yours faithfully,

W. Pole, Esq., C.E., F.R.S. RICHD. HASSARD.

62, Camden Square, London, N.W.,

December 15, 1868.

DEAR SIR,

I HAVE not hitherto had time to go critically into the late drought, nor can I do so for a month at least, but assuming the question to resolve itself into the simple form of—Was there any available rainfall during the months of April, May, June, July, and August? I reply that at most of the Lake stations the fall amounted to between 20 and 30 inches, that is to say, that the fall in those months was more than the average fall in a whole year in the midland and eastern counties.

May, June, and July were dry, especially the latter, but the figures overleaf will show you that a drought in the Lake district is very different from a drought anywhere else.

I need not tell you that in the Cumberland district the winter rains are even more important than elsewhere, and as the drought followed three months in which there had been *between* 30 *and* 40 *inches*, it is obvious that your reservoirs would have been full to overflowing when it set in.

I add a column giving the total fall in eleven months of this dry year.

Yours very truly,

R. Hassard, Esq., C.E. G. J. SYMONS, F.M.S.

RAINFALL in the LAKE DISTRICT, 1868.

	5 Months. April–Aug.	3 Months. May–July.	11 Months. Jan.–Nov.
Berkside - -	22·75	7·25	89·25
Gowbarrow - -	17·00	4·75	53·50
Easedale Tarn - -	24·75	6·75	91·00
Haweswater Measand -	17·25	3·50	55·75
" Mardale -	29·00	11·00	100·58
Seathwaite - -	31·50	10·00	117·25
Watendlath - -	22·44	6·39	81·49
Wet Sleddale - -	26·25	9·50	94·00
Wythburn - -	25·25	6·87	92·75
Average - -	24·02	7·33	86·17
Average, excluding Seathwaite -	23·09	7·00	82·29

Plan

SHEWING THE GATHERING GROUNDS

FROM WHICH THE

Water Supply of the Principal Towns

IN THE MANUFACTURING DISTRICTS OF

Lancashire and Yorkshire

ARE DERIVED.

EXPLANATION.

The gathering grounds and the Towns supplied therefrom respectively are distinguished by the same colour, and the name of the Town is written on the Contributing area.

Scale, 2 Miles to One Inch.

0 ¼ 1 2 4 6 8 10 Miles

RIVER WENNING

RIVER LUNE

LANCASTER

RIVER CONDER

LANCASTER

RIVER COCKER

FYLDE

FLEETWOOD

CARSTANC

RIVER WYRE

RIVER BROCK

PRESTON

CLITHEROE

RIVER RIBBLE

PRESTON

RIVER RIBBLE

LANCASTER CANAL

KIRKHAM

PRESTON

BURNLEY

BLACKBURN

ACCRINGTON

ACCRINGTON

RIVER RIBBLE

BLACKBU

LEEDS A
LIVERPO
CANAL

GENERAL INDEX.

REFERENCES.

The thick figures (thus, **62**) refer to the paragraphs of the Report.
The ordinary figures after a witness's name (thus, *Bateman*, 184) refer to the numbers of the Questions in the Evidence.
The references thus, "App. B." apply to the headings of the Appendices.

A.

Abel, Professor.—Analysis of London Waters; App. AG, AH.
Do., quoted, **184.**
Do., on sewage irrigation, *Burstal*, 6857–62.

Aberdeen, water supply of, *Bain*, 3829–52; *Simpson*, 4723–9, 4751–6.
—— iron pipes at, *Playfair*, 2678–9.

Abingdon, sewage of, *Leach*, 4290.
—— Thames at, App. O, AX.

Absorbent power of soft water, **174**; *Frankland*, 6269–70.
(*See also* Hard and Soft Water.)

Accrington, water supply of, *Bateman*, 277.

Act, Metropolis Water, 1852. (*See* Metropolis Water Act.)
—— Thames Conservancy, 1866. (*See* Thames Conservancy Act.)
—— Sewage, 1867, **126.**

Aëration of Water, *Miller*, 7092–3.
(*See also* Quality of Water.)

Algiers, water at, *Ormsby*, 4557.

Albumen in water (*see* Wanklyn's evidence).

Ammonia in water (*see* Quality of Water).

Ampney, springs at, *Bravender*, 6906; App. O, AX.

Amwell, springs and well at, *Clutterbuck*, 1836; *Muir*, 3969, 4002–7; App. O, AX.
—— analysis of, *Muir*, 4077.

Analysis of waters, on modes and processes of, *Wanklyn*, 5418–97; *Odling*, 6482–4; *Brodie*, 6996–7003; *Miller*, 7104–16.
—— difficulty of, as regards organic matter, **181.**
—— of Lake waters, *Way*, 1454–83.
(*See* Quality. Lake Project.)
—— of Welsh waters (*see* Quality. Welsh Project).
—— of springs (*see* Springs.)

Analyses of London and Thames waters, **152–3, 182.**
By Commission of 1828, **104.**
Commission of 1851, **110, 159, 163, 167, 171, 182**; App. AH.
Hoffman and Blyth, 1856, **113, 182**; App. BG.
Letheby, Odling, and Abel, 1867, **159**; App. AG.
Do., do., 1868, **159**; App. AH.
Frankland and Odling, 1868, **186**; App. AX, BE.
Campbell, *Beardmore*, 3323–5.
Registrar General, **194**; App. AJ; *Farr*, 2847–62.
Wanklyn, 5431; App. AK.
(*See also* Quality of Water.)

Area of Thames basin, **84.**
—— of district supplied by each London water company, **124.**
—— of gathering ground for Welsh project, **12**; *Bateman*, 25–6, 6701–2.
—— of gathering ground for Lake project, **44**; *Hemans*, 319.

Ashton, water supply of, *Bateman*, 277, 6488.

B.

Bain, Alexander, his evidence, 3797–3858.

Bagshot Sands, and the water from them, **78, 80–87**; *Hennell*, 1922, 1929, 2038–9; App. O, AX.
—— in connexion with M'Neill's scheme for supplying London, **80**; *Macneill*, 5817–5958.

Bala Lake, nature of district and water from it, **49**; *Bateman*, 59, 137; *Hassard*, 589–604, 854, 883–98; *Rawlinson*, 1381–1423; *Ramsay*, 1743–8; *Whalley*, 2076–7; *Hawksley*, 2569–72, 2580; *Simpson*, 4620; App. C, D.

Bateman, J. F., his evidence, 1–286, 6485–6748, 7404–7443; App. M.
—— quoted, **23, 39, 60, 135, 164, 168, 172, 221, 225, 240, 247, 253, 254.**
—— pamphlet descriptive of his Welsh project, App. E.
—— essay on constant service, App. I.
—— gaugings of the Thames, *Leach*, 4306–8.

Barbadoes, water in, *Parkes*, 3241.

Barlow, P. W., his evidence, 5959–81.
—— quoted, **74.**

Barnsley, water supply of, *Hawksley*, 7528.

Barton Spring, *Clutterbuck*, 1884.

Basingstoke Canal, proposed supply from, **78**; *Hennell*, 1920–2040.

Banbury, water supply of, App. AJ.

Barrow, River, App. BD.

Beardmore, N., his evidence, 3255–3445, 7444–57.
—— quoted, **136, 140, 142, 143, 164, 185, 225, 240.**

Béchamp, his experiments, *Frankland*, 6334.

Bed of the Thames, changes in the, *Burstal*, 3620–7.

Beddington sewage farm, App. O.

Bedhampton, springs at, *Ewens*, 3693–3703.

Belgravia, water supply in, *Simpson*, 4627–9.

Bermuda, water in, *Parkes*, 3240; *Remington*, 4432–3.

Bibury Spring, *Bravender*, 6906.

Bill for amalgamation of London water companies, 1851, **111.**

Birkenhead, water supply of, *Duncan*, 2328; App. AM.

Birmingham, water supply of, *Bateman*, 269–72; *Hassard*, 852–3; *McClean*, 5690–3, 5734–5; App. AG.

Blackburn, water supply of, *Bateman*, 277–9, 6488.
—— drought at, *Bateman*, 7412–5.

Blackwater River, App. O.

Blackwell, quoted, **140.**

Blyth, analysis by. (*See* Hoffman.)

Board of Health, opinions on the water supply of London, quoted, **109, 150, 160, 163, 166, 170, 205, 237**; *Bateman*, 59–62; *Bain*, 3798–3858.

Boilers, kitchen, incrustations in, **169**; *Miller*, 7124–6.

Bolton, water supply of, *Bateman*, 6488; App. BC.
—— reservoir, *Bateman*, 48.

Boussingault's experiments, **194**; *Frankland*, 6324.

Boston, water supply of, *Simpson*, 4700.

Boxwell Spring, App. O.
(*See also* evidence of *Brown* and *Bravender.*)

Bradford, water supply of, App. AM.
—— drought at, **60**; App. BC.
—— springs at, *Harrison*, 3024.

Brande, Professor, **104.**

Bravender, John, his evidence, 6888–6915.
—— his proposal for water supply to London, **70, 81.**
—— memorandum on Upper Thames basin, App. H.

Brewing, hard and soft water for, *Way*, 1499*a*–1503; *Hawksley*, 2514; *Frankland*, 6360.

Bridgnorth, water supply of, *Bateman*, 273.

Bridgwater Canal, *Rawlinson*, 1331–3.

Brighton, water supply of, *Barlow*, 5964; *Homersham*, 6824–6833.

Bristol, water supply of, App. AM.
—— insufficiency of supply, **58**; App. BB, BC.

Brodie, Sir B., his evidence, 6979–7044.
—— quoted, **164, 184, 201.**
Bromley, well at, *Morris*, 6108.
Brown, T. C., his evidence, 6838–50.
—— quoted, **69–81.**
Burnley, water supply of, *Bateman*, 6488.
Burstal, Capt., his evidence, 3572–3684, 6851–62.
—— quoted, **140, 198–200.**
Bury, water supply of, *Bateman*, 277, 6488.
—— drought at, **60**; App. BC.

C.

Cambridge, water supply of, *Beardmore*, 3351–3; App. I.
Campbell, his analyses of various waters, *McClean*, 5556; *Homersham*, 6796–6809; *Meeson*, 6878.
Canal, Basingstoke. (*See* Basingstoke Canal.)
—— Thames and Severn, *Denton*, 1658–61, App. BJ, BK.
Canterbury, water supply of, App. AG.
Capital of London water companies, **124.**
Carlisle, water supply of, App. AJ.
—— sewage treatment at, *Burstal*, 6853.
Castle Howard, water supply of, *Homersham*, 6793–6803.
Catchment basins of rivers in England and Wales, **3, 252**; App. BN.
Catchwater drains in Lake district, *Hassard*, 711–2.
Caterham, water supply of, **75**; *Wanklyn*, 5431; *Homersham*, 6793–837; App. O, AX.
Caversham Bridge, Thames at, App. O, AX.
Chalk, water supply from the, **73–77, 88, 145–7**; *Hawksley*, 2520; *Harrison*, 3048–58; *Clutterbuck*, 1785–1893; *Beardmore*, 3272–80; *Bain*, 3799–858; *Barlow* 5960–81; *Homersham*, 6821–37; App. O, AF, AX. (*See also* Muir's evidence.)
Charing Cross Well, **123.**
Chapman's mode of analysis. (*See* Wanklyn's evidence.)
Chatham, water at, *Parkes*, 3136, 3201–8.
Chelsea Waterworks Company, description and statistics, **98, 105, 117, 123, 124**; *Simpson*, 4599; App. P.
—— future means and prospects, **231**, App. L.
Cheltenham, water supply of, *Bravender*, 6901.
Cherbourg, iron pipes at, **174**; *Rawlinson*, 1906; *Playfair*, 2680.
Cherwell River, App. O, AX.
Cheshunt, well at, *Muir*, 3984.
Chester, water supply of, *Duncan*, 2328; App. I., AM.
Chiltern Hundreds Waterworks, Homersham, 6799–6809.
Chadwell and Amwell Springs, **97.**
Cholera, communication of, by water, **215**; *Parkes*, 3121–3, 3169–76, 3192–4; *Letheby*, 3898–911. (*See also* Germs of Disease.)
—— in London, **127, 205**; *Simon*, 2755–64, 2820; *Farr*, 2865–82; *Beardmore*, 3388–96; *Letheby*, 3901–8; *Orton*, 4172–239; *Simpson*, 4628–37; *Frankland*, 6252–8.
—— in Liverpool, *Duncan*, 2317–21.
—— in Southampton, *Parkes*, 3162.
Chorley, iron pipes at, **174.**
Churn, River, *Denton*, 1663–4; *Clutterbuck*, 1881–2; *Brown*, 6840–1; *Bravender*, 6901.
City of London, water supply to, *Simon*, 2741–4.
Cirencester, rainfall at, **69**; *Brown*, 6838–42.
—— drainage of, App. O.
Cisterns, house, retained under constant service, **238.**
Claremont, lead in water at, *Simpson*, 4757.
Clark, Dr., on the hardness of water, and on his softening process, **75, 158, 173, 175–6**; *Homersham*, 6762–6837; App. G.
Classification of waters, *Parkes*, 3147–51.
Clay, London, **87.**
—— Weald, **90.**
Clutterbuck, Rev. J. C., his evidence, 1782–1893.
—— quoted, **14, 74, 140, 185.**
Clyde, River, organic matter in, *Smith*, 7188–95.
Coal Measures, pipes laid over, *Duncan*, 2342–3.
Colne, River, Gloucestershire, *Bravender*, 6901.
—— Hertfordshire, **73**; *Hawksley*, 2520; App. O, AX, AY, BE.
Commission, Royal, of 1828, **104, 150, 182.**
—— Royal Chemical, of 1851, **73, 110, 150, 152, 159, 161–2, 167, 171, 174–5, 182, 195**; *Bain*, 3809–38; *Letheby*, 3939, App. AF.
—— Royal, on Drainage of London, 1857, **221.**
—— —— on Rivers Pollution, **126, 142–3, 150, 196, 204.**
Committee, Commons, of 1821, **103.**
—— of 1834, **106.**
—— of 1850–1–2, 110, 238.
—— of 1867, **127, 128, 206, 239, 242, 244.**
Companies, London Water, districts and works, **114–125**; App. AV.
—— provisions and prospects for the future, **230–2.**
Comparison of cost between Welsh and Lake projects, *Hassard*, 1059–60. (*See also* Bateman's evidence.)
Compensation to rivers, streams, and mills, **13**; *Bateman*, 36, 73, 113–5; *Whalley*, 2043; *Duncan*, 2127–37, 2306–16.
Competition between London water companies, **114.**
Conduits, ancient, in London, **95.**
Conduit, for Welsh project, **7, 39, 53**; *Bateman*, 101–2, 146–58, 215–37; *Rawlinson*, 1327–34; *Duncan*, 2411–28; *Hawksley*, 2527, 2534–48; *Parkes*, 3189; *Beardmore*, 3304–11; *Hassard*, 6934–63; App. E, AQ, AR.
—— for Lake project, **47**; *Bateman*, 158–75; *Hemans*, 301–3, 428–33; *Hassard*, 730–57, 765–7, 778–95, 800–17, 823–38, 6934–63.
—— for Dale's project, *Dale*, 1206–68, 1277–9.
—— for Wye project, *Fulton*, 3502–4; 3519–30; 3543–71; 4108–26; 4148–55.
Conservancy of the Thames and the Lee, **126–9, 196–202, 207, 216–7, 248**; *Beardmore*, 3331–43; *Letheby*, 3889–91; *Simpson*, 4586–93, 4638–9, 4652–70, 4733; *Hawksley*, 5074–5, 5097; *McClean*, 5676–82; *Frankland*, 6375–9; *Bateman*, 6607–10. (*See* Evidence of Thorpe, Burstal, and Leach.)
Constant service, system of supply, **128, 228, 233–43, 248, 262**; *Dale*, 1098–1119; *Hawksley*, 2529, 2557–63; *Playfair*, 2720–4; *Simon*, 2745–50, 2767–76, 2827–33, 2843; *Harrison*, 3072–6; *Parkes*, 3162–8; *Beardmore*, 3346–80; *Letheby*, 3912–8; *Muir*, 4054–76; *Orton*, 4211–8; *Simpson*, 4622, 4698–4706; *Holmes*, 4845–98, 4916; *Greaves*, 5155–67, 5202–10; *McClean*, 5587–5636; *Quick*, 6011–56, 6070–93; *Morris*, 6150–60; *Frankland*, 6269–70; *Bateman*, 6589–6604; *Miller*, 7085–6, 7223–8; *Heron*, 7386–90; App. I, AJ.
Contamination of Thames within the tideway, **107.**
—— organic, from Thames basin, **179.** (*See* Quality of Water.)
Control of water supply, **245–50, 263**; *Bateman*, 258–60; *Duncan*, 2429–33; *Hawksley*, 2528–33, 2566–6; *Holmes*, 4899, 4906–26; *Jackson*, 4967–70; *McClean*, 5575–86. (*See also* Heron's evidence.)
Copenhagen, water supply of, *Hawksley*, 2547.
Coral Rag, **91.**
Cockermouth, water supply of; App. AJ.
Coventry, water supply of, *Bateman*, 274.
Cray River, Barlow, 5979–81.
Crossness, well at, *Barlow*, 5978.
Croydon, well and water supply at, *Homersham*, 6833; App. O, AG, AM, AX.
—— sewage irrigation at, **202**, *Simpson*; 4639, 4663–8; *Frankland*, 6378–9; *Burstal*, 6853; App. O, AX.
Culinary purposes, effects of hardness for, **166–9.** (*See* Hard and Soft Water.)
Cultivation in Thames basin, *Parkes*, 3177–88.
—— in Welsh district, **20**; *Hassard*, 979–1025; *Ramsay*, 1781; *Whalley*, 2094–5; App. B.
Cumberland Lakes (*see* Lake Project).

D.

Dale, Thos., his evidence, 1061–1305.
—— quoted, **225, 240.**
—— his project for London water supply, **57**; *Dale*, 1064–1305; App. Q.
Darenth or *Dart*, River, *Barlow*, 5979–81.
Delify Mines, Hassard, 1038, App. B.
Denton, Bailey, his evidence, 1529–1706.
—— quoted, **140.**
—— his project for supplying London, **68, 81**; *Denton*, 1532–1706; App. V.

Derby, water supply of, App. AG, AM.
Derbyshire, proposed supply of London from, **56**; *Remington*, 4324–4442.
Dewsbury, water supply of, *Bateman*, 6488.
Diarrhœa caused by impure water, *Parkes*, 3190.
Diseases communicable by water, **215**; *Parkes*, 3114–23. (*See* Cholera, Fever, Germs.)
Distribution of water in London, **125**; *Simpson*, 4741–3.
—— proposed under Welsh project, **9**; *Beardmore*, 3440–5; *Simpson*, 4618–2; *Bateman*, 6570–4.
Don, River, self purification of, *Hawksley*, 5076.
Dorking, analysis of water at, *Wanklyn*, 5431.
Double Supply in London, *Harrison*, 3110; *Leach*, 4318–20.
Dove, River, proposed supply from, **56**; *Remington*, 4324–4442.
Dover, water supply of, App. AG.
Drainage, land, as affecting water supply, *Denton*, 1529, 1549–54.
—— on the Lee, *Greaves*, 5188–93.
—— area for Lake and Welsh projects. (*See* Area.)
Draught, unequal, of water at various parts of the day, **235**.
Drifts in the chalk, *Harrison*, 3095–3100. (*See* Chalk.)
Drinking, effects of hardness for, **163–5**. (*See also* Hard and Soft Water.)
Droughts in Lake district, *Symons*, 441.
—— of 1864–5; *Bateman*, 6515*a*.
—— of 1868, **59–64**; *Bateman*, 7404–7443; *Beardmore*, 7444–57; *Hawksley*, 7490–7537; App. BB, BC.
Dublin, water supply of, *Hassard*, 549–84, 757*a*; *Bateman*, 7408.
Dudley, water supply of, *Bateman*, 269.
Duncan, Thomas, his evidence, 2097–2454.
—— quoted, **39**, 164–172, **225**, **247**.
Dundee, water supply of, App. AG, AM.
Du Pasquier on dyeing, *Playfair*, 2707.
Durham, water supply of, App. AG.
Dwngwm Mine, *Hassard*, 1038; App. B.
Dyeing, comparison of soft and hard water for, **173**; *Way*, 1504; *Dale*, 1079–83; *Hawksley*, 2515; *Playfair*, 2705–7; *Hawksley*, 5109–12; *Frankland*, 6358–9. (*See* Frith's and Jubb's evidence.)
Dysentery, caused by impure water, *Parkes*, 3190.

E.

Eachus, G. E., his evidence, 2607–2633.
Eastbourne, water supply of, *McClean*, 5639–40; 5723–8.
East London Waterworks, description, statistics, &c., **102**, **105**, **116**, **123**, **124**, **142**; *Farr*, 2865–82; *Greaves*, 5123–5211; App. P.
—— constant service given by, *Beardmore*, 3349.
—— proposed supply from the Thames, and future prospects, **127**, **231**.
East London, cholera in, 1866. (*See* Cholera in London.)
Economy produced by municipal management, **248**.
Edinburgh, water supply of, App. AG, AJ, AM.
Embankment of the Upper Thames, **67**.
Enfield Chase, proposed reservoirs in, **72**. (*See* Mylne's evidence.)
Estimates for Welsh project, **25–27**, **32–35**; *Bateman* 207–37; *Hawksley*, 2529; *Simpson*, 4770–3; *Bateman*, 6564–88; *Hassard*, 7159–67; App. M.
—— for Lake project, **50**, **51**, **53**; *Hassard*, 812–7, 846–51, 1060, 7168–82.
—— for Wye project, *Fulton*, 4093–4107, 4118–22, 4142–7.
Evaporation and absorption, loss of rainfall by, *Bateman*, 28–36; *Hemans*, 325–40; *Symons*, 457–63; *Duncan*, 2121–6; *Hawksley*, 2480; *Harrison*, 2958–66, 3036–40; *Brown*, 6839–40; *Hawksley*, 7504–26.
Ewens, G. W., his evidence, 3685–3796
—— reference to his project, **79**, **81**.

F.

Farnham, action of soft water on iron pipes at, *Way*, 1494.
Farr, Dr., his evidence, 2844–2930.
—— quoted, **184**.
Fencing to conduit for Lake project; *Hassard*, 720–8.
Fever, communication of, **215**; *Simon*, 7127–41. (*See* Diseases, Germs.)
Filtration, **104**, **105**, **124**, **209–212**, **248**; *Simon*, 2795–6; *Parkes*, 3143–6; *Frankland*, 6389–96, 6418–25; App. AG., AT.
—— by oxide of iron, *Miller*, 7089; *Smith*, 7264–5.
—— cost of, *Hassard*, 934; *Bateman*, 6604–5; App. K.
—— necessary for Welsh waters; *Hassard*, 1031–2.
Financial arrangements for Welsh project, **28**; *Bateman*, 6575–88, 6604–57, 6738–48.
Fires, extinguishing, **248**; *Quick*, 6031–7, 6043; App. BL.
—— in Manchester; *Bateman*, 6595–6; *Heron*, 7349–53.
Firth, Jos., his evidence, 5212–5319.
—— quoted, **172**.
Fisheries on the Severn, **38**; *Bateman*, 74–98, 123–132; *Whalley*, 2043, 2053–7.
—— in the Lake district; *Hassard*, 653–5.
—— in Scotland; *Bateman*, 74–98.
Fittings, house, **235**; *Rawlinson*, 1912.
Fleet pond, *Hennell*, 2030–1.
Fleetwood, water supply of; *Bateman*, 277.
Floods, great; *Rawlinson*, 1440–1, 1452.
—— in the Thames, **140**; *Beardmore*, 3323–5; *Leach*, 4271–7; *Hawksley*, 5061–5.
—— in Wales and the Severn, *Bateman*, 36; *Hawksley*, 2463–4; *Bateman*, 6662–6.
Frankland, Dr., his evidence, 6191–6432.
—— quoted, **23**, **24**, **164**, **168**, **172**, **182**, **184**, **186**, **200–2**, **240**; *Burstal*, 6851–62.
—— his analyses and processes, **152–3**; *Wanklyn*, 5420–97; App. AJ. (*See* Registrar General; also evidence by Miller, Brodie, Angus Smith, Morris.)
Frankland and Odling, analysis of Welsh and Cumberland waters, **17**; App. D.
—— Analysis of waters from Thames basin, **159**, **186**; App. AX, BE.
Froxfield, spring at, **88**; *Clutterbuck*, 1837.
Frost, effect of, in New River, *Hawksley*, 2534; *Muir*, 3990–8.
—— in Loch Katrine, *Bateman*, 6671–9.
Frost, anticipated effect of, in conduits of Welsh and Lake projects, **39**; *Bateman*, 244–6; *Duncan*, 2412–7; *Hawksley*, 2527, 2534–48; *Simpson*, 4617–8, 4687–91; *Bateman*, 6669–79.
Forth, navigation of, *Bateman*, 284.
Fullers' earth, **92**.
Fulton, H. H., his evidence, 3446–3571; 4078–4171.
—— his project, **54**; App. AA.
Future influences on the waters of the Thames basin, **195–202**.

G.

Ganges Canal, *Hassard*, 744.
Gases, absorption of, by soft water, **176**.
Gathering ground for Welsh project, **6**, **12**, **18**, **20**; *Ramsay*, 1709–81.
—— for Lake project, **44–53**; *Hemans*, 306; *Hassard*, 755–7; *Ramsay*, 1722–6.
—— for Wye project, *Fulton*, 3449–53
Gaugings of River Thames. (*See* Volume of Water in the Thames.)
Geology of Thames basin, **83**; *Harrison*, 3041–67; *Bravender*, 6902; App. X, Y.
—— of Welsh district, App. B, BA.
—— of Lake district, App. A, AZ.
Germs of disease in water, *Parkes*, 3114–23, 3169–76; *Hawksley*, 5082; *Wanklyn*, 5451; *Frankland*, 6401–4, 6421; *Brodie*, 7032–42; *Simon*, 7137–9; *Smith*, 7209; App. D, AJ.
Gibraltar, water at, *Parkes*, 3200.
Glasgow, water supply of, **26**, **29**, **50**; *Bateman*, 16–18, 59, 64–71, 146–206, 244, 260, 284–6; *Hassard*, 901; *Letheby*, 3942; *Bateman*, 6485–7; App. E, I, AG, AJ, AM, AO, BB.
—— drought at, *Bateman*, 7409–12.
—— mortality at, *Farr*, 2896–2915.
Glenridding Leadworks. (*See* Lead Workings in Lake District.)
Graham, Professor, member of Commission of 1851, **110**.
Grand Junction Waterworks, general description and statistics, **101**, **105**, **119**, **123**, **124**; *Quick*, 5984–98; App. P.
—— future means and prospects, **231**; App. L.
Gravesend, springs at, **74**; *Barlow*, 5961–81.
Gravitation supplies generally, **58–64**; App. BB, BC.

Grays, Essex, waterworks and springs at, **74**, **123**; *Meeson*, 6863–87.
Great Western Railway, conveyance of water to London by, *Whalley*, 2066–75.
Greaves, Charles, his evidence, 5121–5211.
—— quoted, **140**, **143**, **201**, **225**, **240**.
Greensands, **89**, **147**.
Greenwich, rainfall at, **62**.
Grenelle, well at, *Odling*, 6475.
Grenoble, iron pipes at, **174**; *Way*, 1494; *Rawlinson*, 1906; *Playfair*, 2678.
Greta River, *Hemans*, 369; App. A.
Greywell, springs, *Hennell*, 1947.
Groups of provincial towns, supply of, **256**; *Holmes*, 4928–30; *McClean*, 5653–71, 5683–5.
Guildford, water supply of, App. AG.
—— fever at, *Simon*, 7127–48.

H.

Halifax, water supply of, *Dale*, 1149; *Bateman*, 6488; App. AM, BH.
—— droughts at, **60**; *Bateman*, 7408; App. BC.
Hampstead waterworks and wells, *Muir*, 3962–4, 4007.
Hampton, Thames at, **191**; App. O, AX, AY, BE, BG.
Hard and soft waters, comparison of, **174**; *Bateman*, 55–63; *Hassard*, 958–63; *Dale*, 1066–87; *Rawlinson*, 1343–6, 1364–80, 1424; *Way*, 1457–61, 1499–1528; *Clutterbuck*, 1892–3; *Duncan*, 2184–97, 2208–11, 2344–6; *Hawksley*, 2504–15, 2600–1; *Playfair*, 2646–2728; *Simon*, 2777–94; *Farr*, 2883–4; *Parkes*, 3124–42, 3200–18, 3240–5; *Beardmore*, 3344–5, 3381–7, 3429–37; *Letheby*, 3931–42; *Fulton*, 4156–71; *Simpson*, 4623–6, 4678–81; 4722–32, 4751–8; *Hawksley*, 5098–9, 5108–12, 5120; *Firth*, 5212–5319; *Jubb*, 5325–90; *Wanklyn*, 5488–97; *McClean*, 5638–42, 5672–5; *Frankland*, 6259–68, 6352–69, 6427; *Odling*, 6437–46, 6478; *Bateman*, 6680–6700; *Brodie*, 7019–27; *Miller*, 7047–58, 7087, 7093–7, 7124–6; *Smith*, 7217–22, 7259–68; *Heron*, 7343; App. D, G, AG.
Hardness of Thames water, **109**, **113**, **156**, **176**.
Harrison, John Thornhill, his evidence, 2931–3110.
—— quoted, **73**, **136**, **140**.
Hartley, his dock works, *Rawlinson*, 1351.
Hassall, his analysis of Hampshire spring waters, *Ewens*, 3753.
Hassard, R., his evidence, 546–1060, 6916–78, 7149–82.
—— quoted, **14**, **225**, **254**.
—— letter as to rainfall in Lake district, App. BM. (*See also* Hemans and Lake Project.)
Hastings sand, **90**.
Havant, springs at, *Ewens*, 3704–8.
Haweswater Lake, **43–53**; *Hemans*, 335–9, 348–62; *Hassard*, 624–55, 706–10, 768–72; *Dale*, 1169–70, 1190–1205; App. A, F.
Hawksley, Thos., his evidence, 2455–2606, 5055–5120, 7490–7537.
—— quoted, **14**, **16**, **23**, **27**, **38**, **39**, **63**, **140**, **145**, **164** **168**, **172**, **185**, **201**, **221**, **225–240**, **247**; *Duncan*, 2117–37.
Hemans, G. W., his evidence, 287–433.
Hemans and Hassard's project, **41–53**; App. F. (*See also* Lake Project.)
Hennell, Thos., his evidence, 1913–2040.
—— his plan for supplying London, **78**, **81**.
Herbert Hospital, Woolwich, water supply at, *Parkes*, 3135; *Homersham*, 6803–20.
Hertford, sewage treatment at, *Burstal*, 6853.
Heron, J., his evidence, 7269–7403.
—— quoted, **172**, **240**, **247**.
Hoddesdon, well at, *Muir*, 4050–1.
Hoffman, member of Royal Commission of 1851, **110**.
—— and Blyth, analysis of 1856, **113**, **152**, **182**; App. BG.
Holmes, S. F., his evidence, 4774–4963.
—— quoted, **240**.
Homersham, S. C., his evidence, 6762, 6837.
—— quoted, **74**, **175**.
—— works constructed by, *Bain*, 3858*a*; App. O.
Houses, number of, supplied by London companies, **124**.
Hull, water supply of, *Dale*, 1096–1119, 1302–5; *Hawksley*, 2563; *Simpson*, 4701–3.
Hungerford, River Kennett at, App. O, AX.

I.

Impure waters, *Parkes*, 3147–51.
Impurities generally of waters, **194**.
—— organic, of Thames waters, **177–218**. (*See* Quality of Waters.)
Incrustation in boilers (*see* Boilers).
Inorganic contents of water from Thames basin, **154–176**.
Interruption, possible, of flow in long conduits bringing water to London from Wales or the Lakes, **39**, **53**; *Bateman*, 240–6; *Duncan*, 2412–28; *Hawksley*, 2527, 2534–48; *Bateman*, 6643–4, 6685–6.
Iron pipes, action of soft water on, **174**; *Way*, 1490–8; *Rawlinson*, 1894–1912; *Duncan*, 2265–84; *Hawksley*, 2596–8; *Playfair*, 2675–80; *Simpson*, 4723–4, 4751–5.
Itchen River, *Parkes*, 3181, 3195–9.

J.

Jackson, John, his evidence, 4964–71.
Jamaica, water in, *Parkes*, 3240–1.
Jenyns, observations on rainfall, **62**.
Jones, Prof. Rupert, App. O.
Jubb, S., his evidence, 5320–95.
—— quoted, **172**.

K.

Kendal, water supply of, **60**; App. BC.
Kennett River, App. O, AX.
Kent Waterworks, description, statistics, &c., **23**, **122**, **124**, **145**, **208**; *Letheby*, 3863–5; *Morris*, 6094–6190; *Frankland*, 6223–40; App. P, S.
—— their future prospects, **231**.
Keswick, water supply of, *Rawlinson*, 1896–9; App. AJ.
Kimmeridge clay, **91**.
Kingston, sewage of, *Leach*, 4297–9.
Kirkstone Pass, tunnel under, *Hemans*, 399–402; *Hassard*, 717–32, 795–9.

L.

Lake Project, Hemans and Hassard's, for supplying London, **41–53**, **255**, **256**, **258** (*see* evidence of Hemans and Hassard); *Bateman*, 6703–36; App. A, D, F, AZ. (*See also* Conduit, Quality, Quantity, Rainfall, Lead Workings.)
—— Dale's, for supplying northern towns, **57**; App. Q. (*See* Dale's evidence.)
Lambeth Waterworks, general description, statistics, &c., **99**, **105**, **108**, **120**, **123**, **124**; *Simpson*, 4599; App. P.
—— future means and prospects, **231**; App. L.
Lancashire, supply of towns in, *Bateman*, 6488–6512, 6559; *Hassard*, 6919–28.
Lancaster, supply of, *Bateman*, 279; *Rawlinson*, 1896–8; *Bateman*, 6488; App, AJ.
Land, use of sewage on, **196**, **202**. (*See* Sewage.)
Langbourne, springs at, *Ewens*, 3709.
Latham, Baldwin, his sewage works at Croydon, App. O.
Leach, Stephen W., his evidence, 4240–4320.
—— quoted, **136**, **140**, **185**, **198**.
Lead, action of soft water on, **24**, **36**, **174**; *Way*, 1489–91, 1498; *Duncan*, 2299–2302; *Hawksley*, 2599; *Playfair*, 2672–4, 2697, 2725; *Simon*, 2765–6; *Parkes*, 3140–2; *Beardmore*, 3437; *Letheby*, 3870; *Simpson*, 4723–4, 4756–7; *Frankland*, 6264–5; *Homersham*, 6792; *Brodie*, 7016–8; *Miller*, 7117–21; *Smith*, 7266; App. D.
—— workings in Lake district, *Hemans*, 405–13; *Hassard*, 681–91, 758–61; *Dale*, 1170–89; *Way*, 1474–9; *Frankland*, 6212–4; App. A, D.
—— —— in Welsh district, **22**; *Hassard*, 1038–45, 1057; *Ramsay*, 1730–42; *Whalley*, 2048–65; *Bateman*, 6514–5; *Frankland*, 6212–4; App. B, D.
—— —— in Wye district, *Fulton*, 4127–41.
Leakage under constant service system, **235**.
Leamington, water supply of, *Bateman*, 273; App. AG.
Lechlade, Thames at; App. O, AX, BJ.
Lee River, generally, **72**, **127**, **164**; *Muir*, 3951–4077; *Greaves*, 5168–70. (*See also* Evidence of Mylne and Beardmore.)

Lee River, quantity of water obtained from, **142–144**; *Beardmore*, 3312–4; *Greaves*, 5177–9.
—— quality of water from, **203–7**; App. O, AX.
—— proposed reservoirs on, *Greaves*, 5132–9; *Beardmore*, 3438–9.
—— Mylne's plan for improving supply from, **72**. (*See also* Mylne's evidence.)
—— Conservancy, **129, 207**. (*See* Conservancy.)
Leeds, water supply of, *Dale*, 1147; App. AG, AM.
Leicester, water supply of, App. AM.
—— drought at, *Hawksley*, 7490–7526.
—— sewage treatment at, *Burstal*, 6853.
—— self purification of river at, *Letheby*, 3892–3; *Hawksley*, 5079–80; *Odling*, 6453–8.
Letheby, Dr., his evidence, 3859–3946.
—— quoted, **23, 164, 172, 184, 200, 201, 225, 240**; *Morris*, 6108.
—— Odling, and Abel's analyses, App. AG, AH.
—— —— quoted, **152, 159, 182**.
Levels in London to be supplied, *Hawksley*, 2582–9.
Liverpool, water supply of, general particulars, **26, 50**; *Bateman*, 277–9; *Hemans*, 310–16; *Hassard*, 901, 947–52; *Dale*, 1145–6; *Rawlinson*, 1381–1423; *Duncan*, 2101–2454; *Bateman*, 6488; *Hassard*, 6919–21; App. R, AG, AM.
—— peaty water in, *Hawksley*, 2507, 5108.
—— anxiety about interruption of conduit, **39**.
—— scarcity of supply, **58**; *Rawlinson*, 1427, 1438–40; *Duncan*, 2105, 2212–4; *Bateman*, 7416–7; App. BB, BC.
—— proposed addition to supply or supplies from new sources, **255**; *Duncan*, 2142–60, 2215–63, 2286–91, 2322–38, 2356–7, 2453–4; *Hawksley*, 2569–73.
Lime in drinking water; its effect on the animal system, **165**; *Parkes*, 3212–8; *Letheby*, 3933; *Frankland*, 6354.
Lincoln, water supply of, App. AG.
Llanwyddin Reservoir, *Bateman*, 37, 50; *Hassard*, 1046.
Locks on the Thames, *Burstal*, 3684.
Loch Katrine, *Bateman*, 42–5.
—— water of, *Wanklyn*, 5431; *Frankland*, 6273, 6313–4; *Homersham*, 6826.
—— temperature of, **39**; *Bateman*, 244.
—— aqueduct from; *Bateman*, 146–186. (*See* Glasgow, Water Supply of.)
Loch Venachar, *Bateman*, 42–44.
Loddon, River, App. O.
London Bridge Waterworks, **96**.
London clay, **87**.
—— maps of; App. AV, AW.
—— *and Westminster Water Company*, **73**.
—— (*Watford*) *Spring Water Company*, **73**.
Lords, House of, investigation in 1840, **106**.
Lowther, River, *Hemans*, 351–2; *Hassard*, 649–55, 706–10. (*See* Lake Project.)

M.

McClean, John R., his evidence, 5498–5735.
—— quoted, **140, 240**.
—— his project for the supply of London, **67, 81**; App. O, T.
McNeill, Telford, his evidence, 5815–5958.
—— his project for supplying London, **80**.
Maintenance of proposed aqueduct from Wales, *Bateman*, 231–7.
—— of aqueducts at Glasgow and Manchester, *Bateman*, 232–6.
Manchester, waterworks for, and supply of water in, **26, 50, 247**; *Bateman*, 17, 46–8, 59, 65–71, 134–6, 256–60, 277; *Hassard*, 870–3, 901, 948–51; *Hawksley*, 2509; *Simpson*, 4685; *Bateman*, 6488, 6508, 6592, 6603; *Hassard*, 6921–8; *Smith*, 7238–40, 7254, 7266–8; App. E, I, W, AG, AJ, AM. (*See also* Heron's evidence.)
—— fires in, *Bateman*, 6595–6; *Heron*, 7349–53.
—— shortness of water at, **60**; *Bateman*, 7404–8, 7427–23, 7427–30; App. BB, BC.
Manufactories in Welsh district, **21**; *Hassard*, 1026–30; App. B.
Manufacturing purposes, hard and soft water for, **170, 173**. (*See* Hard and soft water.)
Map of rivers of England and Wales and their catchment basins, **3, 252**; App. BN.
—— of Thames basin, **83**; App. Y (1, 2).
—— of districts of the several companies, **114**; App. AV.
Map of Welsh project, App. E (1, 2), BA.
—— of Lake project, App. F (1, 2), AZ.
—— of Dale's project, App. Q, 1.
—— of McClean's project, App. T (1).
—— of Bailey Denton's project, App. V.
—— of Manchester waterworks, App. W.
—— of Mylne's project, App. Z.
—— of Fulton's project, App. AA (1, 2).
—— of rainfall in Wales, App. AT.
—— of population and parishes in London, App. AW.
—— of South Staffordshire waterworks, App. BD.
—— of water supply to various provincial towns, App. BO.
Maple Durwell Spring, *Hennell*, 2014–5.
Marshall's House at Ullswater, *Hemans*, 383–4.
Martin, J., early proposal to bring water from the Colne, **73**.
Maryport, water supply at; App. AJ.
Meeson, R., his evidence, 6863–87.
—— his springs at Grays, **74–81**.
Medmenham, Thames at, App. O, AX.
—— proposed supply from, **67**; *Bateman*, 6737–8. (*See* McClean's evidence.)
Metallic veins and workings in Welsh and Lake districts. (*See* Lead workings).
Meters, water, *Simpson*, 4714–7; *Morris*, 6156–61.
Metropolis Water Act of 1852, **111, 112, 113, 127, 128, 150, 210, 238, 242**.
Metropolitan Board of Works, **128**.
Medley Lock, Thames at, App. O, AX.
Midland counties, water supply of, *Bateman*, 269–75.
Miller, Dr. W. A., his evidence, 7045–7126.
—— quoted, **23, 164–168, 172–184**.
—— member of Commission of 1851, **110**.
—— analysis of Guildford water, *Simon*, 7134.
Miller, Alexander, report on fisheries, *Bateman*, 132–3.
Mimram, River, App. O, AX.
Mineral or inorganic contents of water from Thames basin, **154–176**.
—— workings in Lake and Welsh districts. (*See* Lead workings.)
Mole River, App. O, AX.
Mont Cenis Tunnel, *Hassard*, 795–9.
Moor Park, water at, *Bain*, 3825; *Frankland*, 6338.
Morris, R., his evidence, 6094–6190.
—— quoted, **240**.
Morrys, Peter, his London Bridge waterworks, **96**.
Mortality in towns, as influenced by their water supply, *Playfair*, 2692–3, 2698, 2726–8; *Farr*, 2896; *Letheby*, 3218–26; *Bateman*, 6687–6700.
—— in Sheffield, *Holmes*, 4822–5.
Mountainous districts, supplies from, **3–64, 258**.
Muir, Jos., his evidence, 3947–4077.
—— quoted, **39, 143, 145, 175, 225, 240**.
—— letter as to future means of New River Company, App. BF.
Municipal control of water supply. (*See* Control.)
Myddelton, Sir Hugh, **97**.
Mylne, Robt. W., his evidence, 4972–5054.
—— quoted, **143**.
—— his plan for additional supply from the river Lee, **72, 81**; App. Z.

N.

Navigation of the Severn, *Bateman*, 282–5, 6662; *Hawksley*, 2464.
—— of the Thames, *Harrison*, 3091; *Burstal*, 3611, 3614–3627; *Hawksley*, 5113–5.
Newcastle-on-Tyne, water supply of, and effects of drought in 1868, **58, 60**; App. I, AG, AM, BB, BC.
Newram, spring at, *Hennell*, 2014–5.
New River Company, history, description, statistics, &c., **97, 105, 115, 123, 124, 142**; *Muir*, 3950–4077; *Mylne*, 4976–82; App. P.
—— future means and prospects, **231**; App. BF.
—— interruption by frost, **39**; *Simpson*, 4617.
New York, water supply of, *Simpson*, 4699.
Nile, water of, producing dysentery, *Parkes*, 3190–2.
Nitrogen, nitrates, and nitrites in water, **194**; *Parkes*, 3152–61; *Miller*, 7072–7. (*See also* Evidence of Frankland, Odling, Wanklyn, Brodie, Angus Smith, and Quality of Waters.)

Nomenclature, hydraulic, *Rawlinson*, 1426.
Norwich, water supply of, *Hawksley*, 2561; App. AG, AJ, AM.
Nottingham, water supply of, App. AM.

O.

Odling, Dr., his analysis of various waters, **17, 153**; App. D, AG, AH, AX, BE.
(*See* Frankland and Odling.)
—— his evidence, 6433–6484.
—— opinions on sewage irrigation, *Burstal*, 6851–62.
—— quoted, **24, 164, 172, 184, 186, 200, 201, 202**; *Frankland*, 6386.
Oldham, water supply of, *Bateman*, 277, 6488.
Oolites, springs in, **70, 92**; App. O. (*See* Evidence of Brown and Bravender.)
Organic matters in water, **113, 177–218**; *Bateman*, 136–7, *Hassard*, 983–1025; *Playfair*, 2681–2; *Simon*, 2763–4, 2807–12; *Letheby*, 3880–8; *Wanklyn*, 5401–97; App. BG.
(*See also* Evidence of Frankland, Miller, Angus Smith, Brodie, Odling; also Quality of Water.)
Ormsby, A. S., his evidence, 4443–4560.
Orton, Thos., his evidence, 4172–4239.
Otter's Pool spring, near Watford, *Clutterbuck*, 1833; App. O, AX.
Oxford, Thames at, App. O, AX.
—— drainage of, *Brodie*, 6980–5; App. O.
—— water supply of, *Bateman*, 275.
—— clay, **91**.

P.

Pant Mawr lead mines, *Whalley*, 2053; App. B.
Paper mills on the Thames, *Thorpe*, 5774–93.
Paris, supply of, *Hassard*, 959–62; *Hawksley*, 2544–51, 2602; *Playfair*, 2696–7; *Farr*, 2894–5; *Letheby*, 3932; *Simpson*, 4729*a*–32; *Hawksley*, 5098.
Parkes, Dr. E. A., his evidence, 3111–3255.
—— quoted, **164, 172, 184, 201**.
Peat, effect of, in water generally, *Hassard*, 992–1000; *Hawksley*, 2504–12; *Playfair*, 2685; *Beardmore*, 3431–6; *Letheby*, 3870–2; *Hawksley*, 5108; *Miller*, 7059–61, 7091; *Smith*, 7212–4, 7255–8, 7264–5.
—— in Lake district, *Hemans*, 308, 341–7; *Hassard*, 624–9; *Dale*, 1127–41; *Frankland*, 6203–10, 6313–4; App. A, D.
—— in Welsh district, **23, 36**; *Bateman*, 134; *Ramsay*, 1713–20; *Frankland*, 6203–10, 6313–4; *Bateman*, 6657–62; App. B, D.
—— in water at Manchester, Liverpool, Glasgow, and Sheffield, *Bateman*, 134–6; *Simpson*, 4685; *Holmes*, 4814–9; *Bateman*, 6657–62.
Penrith, water supply of, *Hassard*, 761–2; App. BB.
Percolation in Thames basin, *Harrison*, 2958–66.
Permeable and impermeable strata in Thames basin, **82–94**; *Harrison*, 3041–67.
Pipes in lake conduit, *Hemans*, 428–9; *Hassard*, 742–3, 778–95, 825–30.
—— wooden, in London streets, replaced by iron, **100**.
Playfair, Dr. Lyon, his evidence, 2634–2728.
—— quoted, **24, 164, 172, 184, 240**.
Plumstead waterworks, *Homersham*, 6767–6837.
Plymouth, water supply of, App. AG.
Pole, William, report on Lake district, App. A.
—— quoted, **52**.
—— report on Welsh district, App. B.
—— quoted, **17, 21, 22, 23**.
—— report on Bala Lake, App. C.
—— report on Thames basin, App. O, AY.
—— quoted, **153, 185**.
Pollution of Rivers, Way, 1519–28; *Hawksley*, 2553.
—— —— Commission on. (*See* Commission.)
Poor, water supply to the, **244, 248**; *Simon*, 2743–4, 2830–3; *Beardmore*, 3366–80; *Simpson*, 4621, 4707–17, 4744–50; *Hawksley*, 5100–5, 5116–9; *Greaves*, 5162–7, 5202–10; *Rendle*, 6750–61.
Population of London, **219–223**; *Bateman*, 3–15; *Hassard*, 865; *Hawksley*, 2502; App. E, AH, AW.
—— of Thames basin, **179**; *Hawksley*, 2591–5.
—— on the Severn, *Hawksley*, 2591–5.
Portland stone and sands, **91**.
Potteries, Staffordshire, water supply of, *Hassard*, 593–604.
Pressure in mains, reduced by constant service system, **235**.
Preston, water supply of, *Bateman*, 277, 6488; App. AG, AJ, AM.
—— drought at, **60**; App. BC.
Present water supply of London, **95–129**.
Previous sewage contamination of water, **194**; *Morris*, 6107–13; *Brodie*, 7006–7; *Miller*, 7072–7123; App. D, AJ.
(*See* Evidence of Frankland, Odling, Brodie, and Quality of Water.)
Provincial towns, water supply of, **10, 48, 53, 57, 251–6, 264**; *McClean*, 5587–95, 5653–71, 5683–5725; *Bateman*, 6488–6512; *Hassard*, 6919–28; App. BO.
—— proposed to be supplied by Lake project, *Hemans*, 310–16; *Hassard*, 590–604, 772–7, 852–9, 883–901, 947–57.
—— —— by Welsh project, *Bateman*, 269–275.
—— —— by Dale's project, *Dale*, 1145.
Public supplies of water, **248**.
Pump waters in London, *Letheby*, 3873–9.
Pumping, cost of, *Hawksley*, 2573–8; *Quick*, 6057–8; *Bateman*, 6604–6, 6656–7; App. K.
—— necessary under Welsh and Lake projects, **35, 53**.
—— power of London water companies, **124**.
Putrefaction in water, **174**.
Purification and conservancy of the Thames and Lee, *Simon*, 2815–21, 2837–42; *Burstal*, 3581–95, 3632–68; *Letheby*, 3882–91. (*See* Conservancy.)
Purchase of water companies' interests, *Hawksley*, 2529–33.
(*See also* Welsh project, Financial details, and Control of water supply.)

Q.

Quality of waters supplied to London, and of the water generally from the Thames basin, **104, 128, 149–218, 248, 260**; *Rawlinson*, 1359–60; *Clutterbuck*, 1805–10; *Simon*, 2751–71, 2804–42; *Beardmore*, 3329–30; *Leach*, 4289–96; *Simpson*, 4581–5, 4600, 4623–37, 4656–62, 4678–97; *Wanklyn*, 5398–5497; *McClean*, 5555–8; *Quick*, 5996–6010, 6064–9; *Hawksley*, 2504–12, 2553–6, 5074–83, 5098, 5106–12, 5120; App. D, O, AF, AG, AH, AK, AJ, AX, AY, BE, BG.
(*See also* Evidence of Frankland, Odling, Farr, Miller, Brodie, Angus Smith, Playfair, Letheby, Parkes.)
—— of water from Lake district, **52**; *Hemans*, 300, 306–8; *Way*, 1454–83; *Frankland*, 6200–20; App. A, D, F.
—— of water from Welsh district, **17, 24, 36**; *Bateman*, 57–8, 134–45; *Hemans*, 300; *Hassard*, 979–1045; *Simpson*, 4685; *Frankland*, 6200–20; App. B, D, E.
Quantity of water at present supplied to London, **124**; *Bateman*, 6–10; *Hemans*, 293–4; *Hawksley*, 2467–8, 2516–23; App. N.
—— which will probably be hereafter required for London supply, **219–229, 261**; *Hemans*, 295–9, 317; *Hassard*, 561–2, 859–82, 899–901; *Rawlinson*, 1408–14; *Hawksley*, 2491–2503; *Simon*, 2798–2803; *Harrison*, 3072–85; *Beardmore*, 3326–8; *Fulton*, 3510–2; *Simpson*, 4647–51, 4718–22, 4759–64; *Hawksley*, 5088–92; *Greaves*, 5142–54, 5205–9; *McClean*, 5597; *Quick*, 6059–63, 6082–93; App. E.
—— allowed generally per individual, **224–228**; *Bateman*, 5–20; *Parkes*, 3221–6; *Letheby*, 3927–30, 3943–6; *Muir*, 4058–63; App. I.
—— consumed in various provincial towns, **226**; *Bateman*, 140–2; *Duncan*, 2221–6, 2251–3, 2360–77; *Holmes*, 4802–11; App. AM.
—— which the London companies are empowered to take from the Thames, and which they can hereafter supply, **138, 232**.
—— flowing in the Thames and the Lee, **134**. (*See* Volume.)
—— available from the Thames and the Thames basin, **131–148, 259**; *Denton*, 1532, 1546–7, 1683, 1691; *Beardmore*, 3321–2; *Leach*, 4300–20; *Simpson*, 4572, 4611, 4640–51, 4684; *Hawksley*, 5055–73, 5083–96, 5106–7; *Greaves*, 5180–7; *McClean*, 5637–8; *Thorpe*, 5747–8; *Quick*, 6005–9.
—— available from the River Lee, **142–4**.
—— available from the chalk, **145–7**.
—— available from Lake district, **45**. (*See* Evidence of Hemans and Hassard.
—— available from Welsh district, **11–16**; *Bateman*, 108–110, 122, 7423–6.
Quick, J., his evidence, 5982–6093.
—— quoted, **136, 140, 185, 240**.
—— on the cost of pumping and filtration, App. K.
—— on the future means of certain water companies, App. L.

R.

Rainfall, generally, **61, 62**; *Symons*, 441; *Rawlinson*, 1425–40, 1448–52; App. BB, BC.
—— at Greenwich, **62**; *Hawksley*, 7526.
—— in Thames basin, **84, 133**; *Harrison*, 2943–3040, 3110; *Beardmore*, 3267–89; *Simpson*, 4671–7; *McClean*, 5509–23, 5643–5; App. AC, AD, AE.
—— in Upper Thames basin, **69**; *Brown*, 6838–42; *Bravender*, 6895–9, 6902–3; *Beardmore*, 7444; App. BJ.
—— on the Lee, *Muir*, 4032–9; *Beardmore*, 7444–57.
—— in the Welsh district, **13, 14, 37**; *Bateman*, 23–36, 103–122; *Hemans*, 421–8; *Hassard*, 467–545, 964–78; *Rawlinson*, 1337–41; *Clutterbuck*, 1849–64; *Duncan*, 2407–10; *Hawksley*, 2487; *Symons*, 2729, 2735–6; *Beardmore*, 3290–5; *Bateman*, 6524–39, 7424; App. E., AT.
—— at Bala, *Duncan*, 2287–90, 2332.
—— in the Wye district, *Fulton*, 3454–3507, 4078–92.
—— in the Lake district, **45**; *Bateman*, 23–6, 103–4; *Hemans*, 309–33; *Symons*, 435–545; *Hassard*, 607–23; *Hawksley*, 2470; *Symons*, 2730–5; *Beardmore*, 3300–3; App. B.M.
—— in Lancashire and Yorkshire, *Bateman*, 104; *Duncan*, 2107–37; *Holmes*, 4790–4801; *Bateman*, 6485, 6490–6; *Hawksley*, 7537.
—— in Scotland, *Bateman*, 26–36, 108, 6485.
Ramsay, Professor, his evidence, 1707–81.
Rateable property in London, **26**; *Bateman*, 262–8; App. E.
Rates for water, **103, 250, 263**; *Bateman*, 65–71; *Hemans*, 414–20; *Simpson*, 4771–3.
—— in Manchester, Glasgow, Liverpool, and other provincial towns, **28**; *Bateman*, 189–206; *Hassard*, 873; *Duncan*, 2434–52; *Holmes*, 4907–15, 4937–8; *Bateman*, 6744.
(*See also* Heron's evidence.)
—— proposed for London, **28, 250, 263**; *Bateman*, 247–68; *Hassard*, 910–44; *Bateman*, 6739–46.
Ravensbourne River, **122**; *Morris*, 6100–3, 6138–9, 6189.
Rawlinson, Robert, his evidence, 1306–1425, 1426–1452, 1894–1912.
—— quoted, **14, 140, 164, 168, 172, 225.**
Reading, Thames at, App. O, AX.
—— drainage of, App. O.
Registrar General's Reports, examples of, App. AJ.
—— referred to, **127, 152, 159, 182, 194, 211**; *Simpson*, 4739–40; *Greaves*, 5171–6.
(*See* Quality of Water.)
Remington, S., his evidence, 4321–4442.
—— his project for the supply of London, **56.**
Rendle, W., his evidence, 6749–61.
—— quoted, **240.**
Repairs of mains, **235.**
Reservoirs, on, generally, **63**; *Rawlinson*, 1320–5, 1348–58, 1441–7; *Hawksley*, 7498–7529.
—— of present London water companies, **124.**
—— proposed on the Thames, **139–141**; *Denton*, 1594–5, 1635–40; *Harrison*, 3092–3109; *Beardmore*, 3322, 3399–421; *Burstal*, 3612–3, 3638–9, 3664, 3680; *Leach*, 4248, 4271–86, 4300–18; *Simpson*, 4572–611, 4646; *Hawksley*, 5071–3, 5093–6; *McClean*, 5524–8; *Thorpe*, 5748–59, 5812–4; *Quick*, 6008.
—— proposed on the Lee, **143**; *Beardmore*, 3313–4; 3438–9; *Muir*, 3972–8, 4019–21, 4029; *Mylne*, 4983–5054; *Greaves*, 5178–9.
—— belonging to Welsh project, **6, 8, 15, 16, 40**; *Bateman*, 36–52, 100–102, 115–6; *Hassard*, 1033–7, 1046–55; *Ramsay*, 1724–9, 1749–50, 1777–80; *Hawksley*, 2463, 2469–89; *Bateman*, 6513–4, 6560–3, 6667–8; *Hassard*, 6929–33, 7150–67, 7529; App. AP.
—— belonging to Lake project, **47**; *Hassard*, 818–24, 839–45, 6964–74.
—— belonging to Wye project, *Fulton*, 3475–83, 3508–9, 3519–20, 3557–9.
Reservoir, bursting of, at Sheffield, *Holmes*, 4782–5.
Rivers of England and Wales, and their catchment basins, **3, 252**; App. BN.
Rivers Pollution Commission. (*See* Commission.)
Rivington Pike Works, *Bateman*, 278–9; *Duncan*, 2101–2454. (*See* Liverpool, water supply of.)
Rochdale, water supply of, *Bateman*, 277.
—— drought at, **60**; App. BC.
Roget, Dr., **104.**
Royalty for water, *Whalley*, 2078.
Rugby, sewage treatment at, *Burstal*, 6853.

S.

Salford, see Manchester.
Sands, Bagshot. (*See* Bagshot Sands.)
—— Hastings, **90.**
—— Tertiary, **87.**
Scour of Thames, *Leach*, 4271–7, 4302–3.
Sections, geological, **85**; App. Y 3.
—— of Thames, *Harrison*, 2968; App. AB.
Self-purification of rivers and streams, **180**; *Farr*, 2852–64; *Parkes*, 3180–8, 3195–9, 3250–5; *Letheby*, 3891–7; *Leach*, 4291–6; *Hawksley*, 5075–82; *Wanklyn*, 5482–5; *Frankland*, 6372–4; *Odling*, 6447–58; *Brodie*, 6982–91, 7010–14; *Miller*, 7062–71, 7088–90; *Simon*, 7135–41; *Smith*, 7188–200, 7241–4; App. O. AX.
Separation of water supplies for different purposes, *Simpson*, 4735–8, 4761–4; *Greaves*, 5210–1; *McClean*, 5579–82; *Quick*, 6024–5; *Brown*, 6841.
Separating weirs in Manchester Waterworks, *Bateman* 134–6.
Seven Springs, *Bravender*, 6901; App. O.
Severn, River, area of basin, *Bateman*, 6515*a*.
—— towns and population on, *Hawksley*, 2591–5.
—— head streams of, **6**; *Bateman*, 22; App. B, E. (*See* Welsh Project.)
—— interests upon, **38**; *Whalley*, 2042–96; *Hawksley*, 2460–4, 2580–1; *Simpson*, 4613–6; *Bateman*, 6662–6.
—— navigation of, *Bateman*, 282–5; *Hawksley*, 2464.
—— volume of, *Hawksley*, 2603–6; *Simpson*, 4765–9. (*See* Welsh Project.)
Severn Valley, danger of reservoirs in, **40.**
Sewage, utilization and treatment of, **196, 202**; *Denton*, 1606–22, 1675–81; *Farr*, 2886–93; *Parkes*, 3230–6; *Simpson*, 4638–9, 4663–70; *Frankland*, 6376–9; *Brodie*, 6992–4, 7036–40; *Burstal*, 6851–62; *Miller*, 7078–80; *Smith*, 7204–7; App. O, AX.
—— in drinking water, effects of, *Parkes*, 3114–23. (*See* Quality of Water.)
—— exclusion of, from the Thames, **68, 195–202**; *Hawksley*, 2553–4; *Beardmore*, 3331–43. (*See* Conservancy.)
—— Act, 1867, **126.**
Sheffield, water supply of, *Holmes*, 4774–4971; *Bateman*, 6555–8; App. I, AG, AM.
—— shortness of water at, **60**; App. BC.
Shiplake Mill, App. O.
Shortlands, well at, *Morris*, 6108.
Simon, J., his evidence, 2737–2843, 7127–48.
—— quoted, **164, 172, 184, 201, 240, 247.**
Simpson, James, his evidence, 4561–4773.
—— quoted, **23, 38, 136, 140, 185, 225, 240.**
—— gaugings of the Thames, *Harrison*, 2967–9.
—— letter on the cost of pumping and filtration, App. K.
—— letter as to future means of water companies, App. **L.**
Smith, Dr. Angus, his evidence, 7183–7268.
—— quoted, **23, 164, 172, 184, 201**; *McNeill*, 5888.
Smith, Miles H., mode of analysis. *See* Wanklyn's evidence.
Snow, Dr., quoted, *Farr*, 2881; *Letheby*, 3910.
Soap, waste of by hard water, **157, 170–3**; *Bateman*, 59–63; *Dale*, 1069–74; *Way*, 1516–9; *Hawksley*, 2567–8; *Playfair*, 2646–7; *Simon*, 2782–4; *Hawksley*, 5098; *Firth*, 5217–319; *Bateman*, 6680, 6690–2.
Soap test, Clark's, **158**; App. G.
Soft and hard water, comparison of. (*See* Hard and soft water.)
Softening process, Clark's, **175–6, 178**; *Parkes*, 3207; *Bain*, 3812–58; *Letheby*, 3937; *Muir*, 4026–8; *Morris*, 6126; *Frankland*, 6262–4; *Homersham*, 6762–6837; App. G, O.
Sources of water supply other than mountainous districts, **65–94.**
South Cerney Spring; App. O.
(*See* Evidence of Brown and Bravender.)
South Essex Waterworks, **123**; *Meeson*, 6863–87.
Southampton, cholera and fever at, *Parkes*, 3120, 3162 *Letheby*, 3900.
—— river at, *Parkes*, 3195–9.
Southport, water supply of, App. AG.
Southwark, deficient supply of water in, *Rendle*, 6750–61; App. BL.
Southwark and Vauxhall Water Company, general description and statistics, **102, 105, 121, 123, 124**; App. P.
—— future means and prospects, **231**; App. L.
Springs in Thames basin generally, **85–94.**
—— in oolites and Upper Thames, **70.**
(*See* Brown's and Bravender's evidence.)

Springs at Chadwell and Amwell, **97**; *Muir*, 3951–67.
—— at Gravesend, *Barlow*, 5961–81.
—— at Grays, **78**; *Greaves*, 5194–5201; *Meeson*, 6863–87.
—— on and near the Basingstoke Canal, *Hennell*, 1947, 2012–5.
—— in Hampshire, **78**; *Ewens*, 3687–3796.
—— in the Severn, *Hawksley*, 2606.
—— at Bradford, *Harrison*, 3024.
Staffordshire towns, supply of, *Bateman*, 269; *McClean*, 5587–95, 5653–71, 5683–5735.
—— *South*, waterworks, App. BD. (*See* McClean's evidence.)
Staines, Thames at, App. O, AX, AY, BE.
Stalybridge, water supply of, *Bateman*, 277, 6488.
Stanmore, proposed reservoir at, **7, 8**. (*See* Bateman's evidence.)
Statistics of present water supply, **124**.
Stephenson, Robert, his report on supplies from the chalk at Watford, **73**; *Homersham*, 6822.
St. Helen's, water supply of, *Bateman*, 277.
St. John's Bridge, Lechlade, Thames at, App. O.
Stockport, water supply of, *Bateman*, 277; App. BC.
Storage reservoirs, on, generally, **63**; App. BB.
Storage, in Welsh district, **15**.
—— in Lake district, **46**.
Stourbridge, water supply of, *Bateman*, 272.
Strata, permeable, **85–94**.
Stye, rainfall at the, *Symons*, 441–458.
Subterranean stores of water in Thames basin, **85–94**; *McClean*, 5520; *Brown*, 6840–50.
Summary of conclusions and recommendations by the Commission, **257–264**.
Sunderland, water supply of, App. AG, AM.
Suspicious waters, class of, *Parkes*, 3147–61.
Symons, G. T., his evidence, 434–545, 2729–36; App. AT.
—— quoted, **14, 45, 62**; *Bateman*, 6524.
—— letter on rainfall in lakes, App. BM.
Syreford Spring, *Bravender*, 6901; App. O, AX.

T.

Taunton, his gaugings of Thames, &c.; App. BJ.
Taylor, John, his evidence, 7458–89.
—— reports on gravitation supplies, and drought in 1868, **59–60**; App. BB, BC.
Tea, soft and hard water in making, **167–8**; *Way*, 1505–16; *Frankland*, 6361.
Teddington lock and weir, *Burstal*, 3607–9; *Leach*, 4259–68, 4306–10.
Telford, Thomas, member of Royal Commission of 1828, **104**.
—— his proposed new sources of supply, **73–106**.
Temperature of Glasgow conduit, **39**; *Bateman*, 244.
Tertiary sands, **87**.
Thame, River; App. O, AX.
Thames, towns and population on the, *Hawksley*, 2591–5.
—— volume of. (*See* Volume. Quantity.)
—— not affected by drought of 1868, **64**.
—— Conservancy Act, **126, 150, 196–202**.
—— and Severn Canal; App. BJ, BK.
Thames-head spring, *Bravender*, 6899; App. O, AX.
Thames basin, on the supply of water from the, present and future, and on its geological and hydrological character, **66–70, 82–94, 130–218**; App. H, O. (*See* Evidence of *Denton, Clutterbuck, Brown, Brown. Bravender, Harrison, Beardmore, Burstall, Thorpe, Leach; also* Quantity and Quality of Water.
—— maps of the, **83**; App. Y (1, 2).
Thirlmere Lake, **43–53**; *Hemans*, 362–78; *Hassard*, 656–72, 741, 768–771; App. A. (*See* Lake Project.)
Thorpe, J. H., his evidence, 5736–5816.
—— quoted, **140–198**.
Tide at Richmond, *Burstal*, 3672–4.
Tidal action in the Thames, *Hawksley*, 5059–69.
Trefeglwys reservoir, *Bateman*, 41–46, 50; *Hassard*, 1048–9.
Trench, Dr., report on Liverpool waters, *Duncan*, 2187.
Tributaries to the Thames, *Harrison*, 3020–4; App. O, AX.
Trinidad, water in, *Parkes*, 3241.
Tunnel under Kirkstone Pass, *Hemans*, 399–402; *Hassard*, 717–32, 795–9.
—— under Matterdale Common, *Hassard*, 712–7, 729.
Tyler, Captain, investigation as to water supply in East London, **205**; *Beardmore*, 3393–4.
Typhoid fevers communicable by drinking water, *Parkes*, 3114–3123, 3169–76.

U.

Ullswater Lake, **43–53**; *Hemans*, 373–99; *Hassard*, 673–704; *Dale*, 1151–89; App. A, D, F.
Useable waters, *Parkes*, 3147–51.

V.

Van mine, *Hassard*, 1039; App.B.
Varnish for iron pipes, *Rawlinson*, 1906–11; *Duncan*, 2278–82; *Hawksley*, 2596; *Bateman*, 6586–7.
Vauxhall Water Works Company, **102**.
Verulam, River, proposed supply from, **73**.
Vienna, water supply of, *Letheby*, 3932.
Voelcker, his analysis of springs at Grays, *Meeson*, 6879.
Volga, River, 3190.
Volume of water in the Thames, **131–141**; *Harrison*, 2966–3040, 3086–3110; *Beardmore*, 3260–80, 3315–22, 3424–8; *Burstal*, 3628–31; *Leach*, 4243–70; *Simpson*, 4569–71, 4601–11; *Hawksley*, 5067–8; *McClean*, 5517–20, 5715–8; *Bateman*, 6515*a*–22, 6540–54, 7442–4; *Taylor*, 7472–89.
—— in the Upper Thames, *Brown*, 6840; *Bravender*, 6901; App. BJ.
—— in the River Lee, **142–144**. (*See* Lee, River.)
Vyrnwy, River, App. B, D, E. (*See* Welsh project and Bateman's Evidence.)

W.

Wakefield, water supply of, *Miller*, 7089; App. AG.
Wallingford, sewage of, *Leach*. 4290.
Walsall, water supply of, *Bateman*, 269.
Wandle, River, **202**; *Burstal*, 3656–7; App. O, AX.
—— proposed supply from, **73**.
Wanklyn, Professor, his evidence, 5396–5497.
—— quoted, **184, 209**.
—— remarks on the London waters, App. AK.
—— his modes of analysis, *Frankland*, 6196–9. (*See also* Brodie's evidence.)
Warehouses in Southwark, App. BL.
Warrington, water supply of, *Bateman*, 277; *Duncan*, 2331.
Warwick, water supply of, *Bateman*, 272.
Washing, use of hard water for, **170, 173**. (*See* Hard and soft water.)
Waste of water, **235**; *Hawksley*, 2490; *Greaves*, 5204–9; App. I. (*See also* Constant service.)
Waterworks Clauses Act, 1847, **236**.
Watford, proposed supply from, **73, 110**; *Clutterbuck*, 1834–5; *Bain*, 3799, 3858; *Homersham*, 6822–3.
—— springs at, App. O, AX.
Way, J. T., his evidence, 1453–1528.
—— quoted, **24, 164, 168, 172**.
—— analysis of Lake waters, App. F.
Weald clay, **90**.
Wednesbury, water supply of, *Bateman*, 272.
Weirs, effect of, on the Thames, App. O.
Wells in London, *Letheby*, 3873–9; *Wanklyn*, 5431, 5473–5; *Frankland*, 6339–41; App. AG.
—— of New River Company, *Muir*, 3968–4077.
—— of Kent Water Company, **122**. (*See* Morris's evidence.)
—— in Thames basin, *Clutterbuck*, 1790–3, 1801–3, 1812–26, 1872; *Harrison*, 3048.
—— at Charing Cross, **123**.
—— in New Red Sandstone, *Duncan*, 2101, 2175–2211, 2347–59.
—— at Cirencester, *Bravender*, 6901.
—— at Crossness, *Barlow*, 5968.
—— at Croydon. (*See* Croydon.)
—— at Grenelle, *Odling*, 6574.
Welsh project, Bateman's, for supplying London, **4–10**; App. E. (*See* Bateman's Evidence.)
—— summary of evidence as to, **11–29**.
—— remarks by the Commission on, **30–40, 258**.
—— gathering ground and district generally, App. B, E, BA.; *Bateman*, 22.
—— conduit. (*See* Conduit.)
—— reservoirs. (*See* Reservoirs.)

Welsh project, quality of water. (*See* Quality of Water.)
—— Duncan's remarks on, *Duncan*, 2404–28.
—— Simpson's remarks on, *Simpson*, 4613–19.
West Indies, water in, *Parkes*, 3240–2.
West Middlesex Water Company, general description and statistics, **101**, **105**, **118**, **123**, **124**; App. P.
—— future means and prospects, **231**; App. L.
Wey, River, App. O, AX, AY, BE.
Whalley, G. H., his evidence, 2041–2096.
Whitehaven, water supply of, App. AJ.
—— iron pipes at, *Rawlinson*, 1906.
Whitewater, spring at, *Hennell*, 2013.
Wholesome waters, class of, *Parkes*, 3147–51.
Wigan, water supply of, *Bateman*, 277–9, 6488.
Williamson, Professor, analysis of Kent Company's water, *Morris*, 6190.
Windermere, rainfall at, **62**.
—— supply to Liverpool from, *Hawksley*, 2572–3.
Windsor, drainage of, *Leach*, 4289–96; App. O.
—— lead in water at, *Simpson*, 4757.
—— Thames at, App. O, AX.
Winterwell Spring, Bravender, 6901.
Wolverhampton, water supply of, *Bateman*, 269–72; App. AM.
Woolwich, wells at, *Morris*, 6120–1.
Worcester, water supply of, App. AG.
Works of the various London companies, **124**.
Wormley, well at, *Muir*, 4000.
Worthing, water supply of, App. AJ.
—— sewage treatment at, *Burstal*, 6853.
Wye project, Mr. Fulton's, **54**; *Fulton*, 3446–3571.
—— River, head waters of the, *Bateman*, 22.

Y.

York, water supply of, App. AG.
—— Buildings Waterworks, **98**.
Yorkshire waters, quality of, *Way*, 1487–8.

ALPHABETICAL LIST OF WITNESSES,

With references to the principal Subjects of their Evidence, and the Numbers of the Questions corresponding thereto.

BAIN, ALEXANDER (29th May 1867) - - *Page* 228
References to Reports of the Board of Health, and of the Chemical Commission of 1851, on the metropolis water supply; and recommendation of the water from the chalk - - *Question* 3797–3858
List of waterworks constructed by Mr. S. C. Homersham to supply spring water softened by Dr. Clark's process (at end of evidence).

BARLOW, P. W. (27th June 1867) - - - *Page* 327
Information as to water procurable from chalk springs in North Kent - - - *Question* 5959–81

BATEMAN, JOHN FREDERIC (6th February 1867) - *Page* 1
Population of the metropolis, present and prospective - - - - - *Question* 3–4
Quantity of water supplied in London - - 5–15
Quantity supplied in Glasgow, Manchester, and other towns - - - - - 16–20
Sources most eligible for the water supply of London - - - - - 21
Rainfall of Welsh district - - - 23–24
Area of ditto - - - - - 25–26
Rainfall, and proportion available - - 26–36
Reservoirs for storage - - - - 36–52
Additional districts available - - - 45
Gauging of the streams - - - 53–54
Advantage of soft water - - - 55–63
Quality of water from Wales - - - 57
Supply of Glasgow from Loch Katrine - 64–71
Compensation to mills - - - - 73
Fisheries - - - - - 74–98
Levels of various parts of the work 100–102
Second Examination (7th February 1867) - *Page* 10
Rainfall in various parts of England - *Question* 103–8
Reservoirs and storage of water - - 109–115
Levels of various parts of the work - - 116–118
Rainfall - - - - - 119–122
Fisheries - - - - - 123–133
Peat in Welsh district, and its effect on the water - - - - - 134–136
Organic impurity in Welsh waters - - 137–139
Quantity of water consumed in Glasgow and Manchester - - - - - 140–142
Analyses of Welsh waters - - - 143–145
Description of conduit conveying Loch Katrine water to Glasgow - - - - - 146–158
Conduit proposed to bring water from Wales to London - - - - - 158
General reasons for his preference of the Welsh district for the supply of London - - - 158–167
Further evidence as to the Welsh conduit - 168–175
Ditto as to the Glasgow conduit - - 176–186
Financial arrangements in Glasgow consequent on the introduction of the new waterworks - 187–201
Ditto in Manchester - - - - 202–206
Estimate for Welsh conduit - - 207–216
Reservoirs - - - - - 217–218
Further evidence as to Welsh conduit - 219–230
Maintenance of conduit - - - 231–237
Financial arrangements for Welsh project - 238–239
As to the danger of having the population of London dependent on one supply of water; of interruptions to the flow in the conduit by frost, &c. - 240–246
Financial arrangements proposed; rates for water, &c. - - - - - 267–268
Provincial towns on the line of conduit proposed to be supplied - - - - 269–275
Other projects for supplying London - - 276
Remarks on the water supply of several towns in the manufacturing districts - - - 277–279
Maps promised - - - - 280–281
Interference with the navigation of the Severn 282–285
Length of time necessary to complete Welsh works - - - - - 286
Third Examination (4th March 1868) - - *Page* 356
Particulars of rainfall in different localities, indicating the effect of mountain ranges - *Question* 6485
Particulars as to the Loch Katrine aqueduct *Qu.* 6485–7
Particulars as to the supply of water to manufacturing towns in the North of England - 6488–6512
Further explanations as to various points in regard to the Welsh project - - - 6513–5a
Volume of the Thames in drought - 6515a–22
As to the rainfall in the Welsh district - 6523–39
Fourth Examination (5th March 1868) - - *Page* 367
Gaugings of the volume of the Thames in dry seasons - - - *Question* 6540–54
On the water supply of Lancashire manufacturing towns - - - - 6555–9
Explanations as to the reservoirs proposed in the Welsh project - - - - 6560–63
Explanations as to the estimates for the Welsh project, and as to the proposed arrangements for the delivery of water in London - - - 6564–74
Explanations as to the financial and administrative details for the Welsh project, and further particulars as to the distribution - - - 6575–88
As to the constant service system; with particulars as to the advantages of its application in Manchester - - - - 6589–6604
Further financial details; and comparison of cost of getting certain quantities of water from the Thames and from Wales respectively - - 6604–15
Table of minimum and average rainfall - - 6615
Fifth Examination (11th March 1868) - - *Page* 386
Further explanations as to the comparative estimates for the Welsh project - - *Question* 6616–56
As to peat in the water - - - 6657–62
Effect of the Welsh project on the navigation of the Severn - - - - - 6662–6
As to the danger of large reservoirs - - 6667–8
As to the danger of freezing in the aqueduct 6669–79
Hard and soft water - - - 6680–4
Danger of interruption to the flow in the conduit - - - - - 6685–6
Influence of the quality of water supply on the mortality of towns - - - 6687–6700
Area of catchment ground available for Welsh scheme - - - - - 6701–2
Objections to Messrs. Hemans and Hassard's project for supplying London from the Lakes - 6703–36
Objections to Mr. McClean's project - 6737–8
Financial result of the Welsh scheme - 6738–47
Sixth Examination (9th December 1868) - *Page* 464
Information as to the effects of the drought of 1868 on the water supply of Manchester - *Question* 740–8
Ditto as regards Halifax and Dublin - - 7408
Ditto as regards Glasgow - - - 7409–12
Ditto as regards Blackburn - - 7412–15
Ditto as regards Liverpool - - - 7416–7
Further observations on drought at Manchester, 7417–7423
Calculations as to the rainfall in and supply from the Welsh district - - - - 7423–4
Quantity supplied to London in 1866–7–8 - 7424–6
Further general remarks on the drought - 7427–41
Volume of the Thames in 1868 - - 7442–3

BEARDMORE, NATHANIEL (16th May 1867) - *Page* 202
On the rainfall and quantity of water flowing in the Thames and the Lea - - *Question* 3255–89
Rainfall in the Welsh district - - 3290–5
Flow of the Thames - - - - 3296–8
On the Welsh and Lake projects for supplying London - - - - - 3299–3311
Capabilities of the river Lea - - - 3312–4
Ditto of the Thames - - - 3315–22
Analysis of Thames water at Oxford - 3323–5
Quantity of water necessary per head per diem 3326–7
Capacity of the Thames as a source of supply - 3328
Quality of water from Thames and Lea - 3329–30
Drainage of towns on the river - - 3331–5
Further remarks on additional supplies from the Thames and Lea - - - - 3336–43

Hard and soft water - - *Question* 3344–5
Constant service system - - - 3346–80
Hard and soft water - - - - 3381–7
As to the connexion of the water supply with the cholera in the east of London - - 3388–96
Flow of the Severn - - - - 3397–8
Capability of the Thames basin for increased supplies. Adaptation of large reservoirs - - 3399–3421
Flow of the Severn - - - - 3422–3
Flow of the Lea - - - - 3424–8
Hard and soft water - - - 3429–36
Action of soft water on iron pipes - - 3437
Capability of the Lea for increased supply - 3438–9
Difficulty of introducing into London a delivery of water by gravitation - - - 3440–5
Second Examination (9th December 1868) - *Page* 477
Information as to the effects of the drought of 1868 on the Lea and the Thames - *Question* 7444–57

Bravender, John (18th March 1868) - - *Page* 421
Information as to the geology of the upper basin of the Thames, as to the rainfall and the rivers and springs in the neighbourhood; with suggestions for the supply of London from pure waters in that district - - - *Question* 6888–6915

Brodie, Sir Benjn., Bart. (25th March 1868) - *Page* 430
On the effect of sewage discharged into rivers; and on the self-purification of streams - *Question* 6979–91
On the application of sewage to land - 6992–4
On the methods adopted for the determination of organic matter in water - - 6995–7009
Sewage in water - - - - - 7010–14
As to the action of soft water on iron and lead pipes - - - - - 7015–8
Effect, on soft water, of a long flow in aqueducts - - - - - 7019–21
On soft and hard waters - - - - 7022–7
Sewage in water - - - - 7028–35
Utilization of sewage - - - - 7036–40
Effect of drinking water on the health of towns 7041–4

Brown, T. C. (18th March 1868) - - *Page* 413
On the rainfall at Cirencester; and the storage in the permeable strata of the neighbourhood. Suggestions in regard to the utilization of the springs in the oolite - - - - *Question* 6838–49

Burstal, Capt. E., R.N. (23rd May 1867) - *Page* 219
Constitution and duties of the Thames Conservancy Board - - - - *Question* 3572–98
Quantity of water which the water companies are empowered to draw from the Thames; its effect on the river - - - - 3599–3611
Possibility of increasing the quantity - - 3612–5
Quality of the water - - - - 3616–9
Alterations of the bed of the river - - 3620–7
Quantity flowing in the Thames - - 3628–31
Proposed exclusion of sewage - - 3632–7
Formation of reservoirs in the Upper Thames 3638–9
Power of the Conservancy Board in regard to the purification of the river, locks, gaugings, &c. 3640–84
Second Examination (18th March 1868) - *Page* 417
Proceedings of the Thames Conservancy Board as to the exclusion of sewage from the Thames, and its utilization on land, &c. Reports of chemists thereon - - - - *Question* 6851–62

Clutterbuck, Rev. James (13th March 1867) *Page* 107
Geological nature of the Thames basin; percolation and storage of the water therein, particularly in the chalk strata - - - *Question* 1782–1847
On the rainfall in the Welsh district, and quantity of water obtainable therefrom - - 1848–66
On the Thames basin (*continued*) - - 1867–93

Dale, Thomas (21st February 1867) - - *Page* 71
His engineering experience - - *Question* 1061–5
Comparison of soft and hard water - - 1066–87
Quantity required per head - - 1088–95
Particulars as to the water supply of Hull, and as to the constant service system - - 1096–1119
General particulars of witness's project for supplying water from the Lake district to various towns in Lancashire and Yorkshire - - 1120–1301
On the supply of Hull - - - 1302–5

Denton, Bailey (7th March 1867) - - *Page* 94
On water supply and land drainage generally, *Question* 1529–31
Sufficiency of the Thames to supply London; proposal of witness on the subject - - - 1532–46
Area of drainage, rainfall, &c. in the Upper Thames Basin - - - - - 1547–9
Effect of drainage and subterranean storage - 1550–4
Further particulars as to his project *Question* 1555–1602
Proposed interception and utilization of the sewage, 1603–22
Further evidence as to his project - - 1623–75
Sewage interception, &c. - - - 1675–82
The Thames sufficient as a source of supply for London, and preferable to sources in Wales or Cumberland, 1673–93
On the quality of the present London waters, 1694–1706

Duncan, Thomas (21st March 1867) - - *Page* 122
On the supply of water to Liverpool, present and future *Question* 2097–2403
Remarks on the project for supplying London from Wales - - - - - 2404–28
On the municipal control of water and gas-works, 2429–33
On the supply of Liverpool (*continued*) - 2434–54

Eachus, G. E. (27th March 1867) - - *Page* 155
Sources of water should be applied only to the supply of towns in the locality near them, and not to towns at a distance - - - *Question* 2607–33

Ewens, G. W. (23rd May 1867) - - *Page* 224
Information as to certain large springs in Hampshire, from which witness conceives the metropolis might be supplied; project for the purpose *Question* 3685–3796

Farr, Dr. William (8th May 1867) - - *Page* 172
On the analyses of London waters published by the Registrar-General - - *Question* 2844–62
Self-purification of rivers - - - 2863–4
On the outbreak of cholera in the east of London in 1866, and the connexion of the water supply therewith - - - - - 2865–82
Comparison between hard and soft water - 2863–4
Conditions of purity of water; supplies of London and Paris - - - - - 2885–95
Influences of water supply on the mortality of towns, 2896–2928
Present condition of London water - - 2929

Firth, Josiah (20th June 1867) - - *Page* 296
Comparison of hard and soft water as used in the cloth manufacture - - *Question* 5212–5319

Frankland, Dr. E. (27th February 1868) - *Page* 338
On the method of analysing potable waters, *Question* 6191–9
On the quality of the water from the Welsh and Lake districts - - - - - 6200–14
On the quality of the waters supplied to the metropolis - - - - - 6215–58
On hard and soft waters - - - 6259–68
On the system of constant service - - 6269–70
Quality of Welsh and Cumberland waters - 6271–7
On the organic contamination of drinking waters 6278–6351
Comparison between hard and soft waters - 6352–69
On the sewage contamination of the Thames, 6370–6417
Filtration - - - - - - 6418–25
Conditions of good drinking water - - 6426–8
Sewage contamination - - - 6429–32

Fulton, Hamilton H. (16th May 1867) - *Page* 216
Explanation of his project to supply London with water from the head streams of the Wye, *Question* 3446–3571
Second Examination (30th May 1867) - *Page* 246
Further particulars as to his project *Question* 4078–4171

Greaves, Charles (6th June 1867) - - *Page* 291
Sources of supply of the East London Waterworks Company - - - *Question* 5121–31
Capacity of increase from the river Lea - 5132–41
Quantity required for supply of London; experiments to determine this - - - - 5142–67
Quality of water from the Lea - - 5168–76
Capacity of the Thames basin generally for water supply - - - - - 5177–87
Effect of exclusion of sewage from the Lea - 5188–93
Springs in the chalk - - - 5194–5201
On the constant service system as applied to poor districts - - - - - 5202–10
Separation of supplies for different purposes 5210–11

Harrison, John Thornhill (9th May 1867) *Page* 179
On the rainfall and evaporation in the Thames basin; the quantity discharged by the river; the storage in the subterranean reservoirs; the geology of the district; and various other data as to the Thames basin generally - - *Question* 2931–3110

HASSARD, RICHARD (14th February 1867) - *Page* 44
His experience in regard to the supply of Dublin, *Question* 546–584
General explanations of the project of himself and Mr. Hemans for supplying London from the lakes of Cumberland and Westmoreland - 585–604
Rainfall in the district - - - 605–623
Project as regards Haweswater - - 624–655
As regards Thirlmere - - - 656–672
As regards Ullswater - - - 673–703
General explanations - - - 704–712
Tunnel from Thirlmere to Ullswater - 712–717
Catchwater drains - - - - 718–729
Conduit to London - - - - 730–754
Geological character of the ground - 755–757
Second Examination (20th February 1867) - *Page* 53
Particulars as to the Dublin waterworks (at commencement of evidence).
Lead workings in Ullswater - *Question* 758–764
Construction of conduit - - - 765–769
Alterations of levels of lakes - - 768–772
Supply of provincial towns along the line of conduit, 772–777
Discharge of large water-pipes, and of conduits, 778–795
Tunnel under Kirkstone Pass - - 795–799
Conduit to London - - - - 800–817
Proposed store reservoir at Edgeware - 818–824
Geological nature of the line of conduit - 825–838
Edgeware reservoir - - - - 839–845
Estimate for the project - - - 846–851
Provincial towns proposed to be supplied on line of conduit - - - - - 852–859
Present and future demand of water for London, 859–883
Additional supply from Bala Lake - - 884–898
Supply of provincial towns - - - 899–901
Financial scheme, with cost of water in Liverpool, Manchester, and Glasgow. Proposed water rates, &c. - - - - - 901–944
Aberdeen waterworks - - - 945–946
Supply of provincial towns - - - 947–957
Comparison of soft and hard water - - 958–963
Objections to Welsh project, as to insufficiency of rainfall - - - - - 964–978
Do. as to nature of drainage area and quality of water, 979–1032
Ditto as to reservoirs - - - 1033–1037
Ditto as to mineral workings - - 1038–1045
Ditto as to reservoirs - - - 1046–55
Ditto as to mineral workings - - 1056–8
Comparative cost of obtaining water by Lake and Welsh projects - - - - 1059–60
Estimate for Lake project (at end of evidence).
Third Examination (19th March 1868) - *Page* 426
Answer to Mr. Bateman's objections to the Lake project, and further explanations in reference thereto, *Question* 6916–78
Fourth Examination (26th March 1868) - *Page* 442
Answer to the objections of Mr. Bateman to the Lake project, and comparison of the same with that from Wales - - - *Question* 7149–82

HAWKSLEY, THOMAS (27th March 1869) - *Page* 137
General remarks on the project for supplying London with water from North Wales - *Question* 2455–64
Rainfall in Wales, &c.; probable quantity of water procurable - - - - - 2465–87
Quantity of water required for London - 2488–2503
Quality of water most suitable for the metropolitan supply - - - - - 2504–15
Quantity at present used in London - 2516–24
Further remarks on the Welsh project - 2525–33
Liability of stoppage in the conduit from frost or other interruption - - - - 2534–48
Water supply of Paris - - - 2549–51
Supply of London from the Thames - 2552–6
On the constant service system - - 2557–63
On the municipal control of waterworks - 2564–6
Comparison of hard and soft water - - 2567–8
On the supply of Liverpool - - 2569–77
On the Welsh and Lake projects for supplying London, 2578–91
On the population of the basins of the Thames and the Severn, with tables - - - 2591–5
Action of soft water on iron and lead pipes 2596–2601
Supply of Paris - - - - - 2602
Quantity of water passing down the Severn - 2603–6
Second Examination (6th June 1867) - - *Page* 286
Capacity of the Thames to supply London; quantity which might be taken therefrom - *Question* 5055–73
On the self-purification of streams; instance of the rivers at Sheffield and Leicester *Question* 5074–81
On the communication of cholera by germs in drinking water - - - - - - 5082
Capacity of the Thames basin as a source of water supply - - - - - - 5083–7
Quantity per head required for London - 5088–92
On the construction of reservoirs on the Upper Thames, with a view of increasing the supply - 5093–6
Population and sewage in Thames basin - 5097
Comparison of hard and soft water - - 5098–9
On the constant service system - - 5100–5
Sufficiency of the Thames - - - 5106–7
Hard and soft water - - - 5108–5112
Effect of abstraction of water on the navigation of the Thames - - - - - - 5113–5
Supply to the poor - - - - 5116–9
Keeping qualities of hard and soft water - 5120
Third Examination (10th December 1868) - *Page* 482
On the deficiency of water supply during the year 1868; and on the construction of reservoirs for storage - - - *Question* 7490–7537

HEMANS, GEORGE WILLOUGHBY (13th February 1867), *Page* 27
Has elaborated his project in connexion with Mr. Hassard - - - *Question* 287–292
Quantity of water required in London, present and future - - - - - - 293–299
General description of Lake project - - 300
Proposed conduit to London - - 301–303
Further general description - - - 304–306
Clearness of the water - - - 307–308
Rainfall, and quantity of water available - 309–333
Haweswater Lake - - - 334–339
Absorption and evaporation - - 340–341
Peat in the district - - - - 341–347
Project as regards Haweswater - - 348–362
Ditto as regards Thirlmere - - - 362–378
Ditto as regards Ullswater - - - 378–399
Tunnel under Kirkstone Pass - - 399–402
Analysis of the water - - - 403–404
Lead mines in the district - - - 405–413
Financial proposition; rates for water - 414–420
Rainfall in Wales - - - - 421–428
Conduit - - - - - 429–433

HENNELL, THOMAS (20th March 1867) - *Page* 115
Explanations as to his project for supplying London with water brought by the Basingstoke canal, *Question* 1913–2040

HERON, JOSEPH (2nd April 1868) - - *Page* 454
Particulars as to the water supply of Manchester, *Question* 7269–7403

HOLMES, S. F. (6th June 1867) - - *Page* 273
On the water supply of Sheffield *Question* 5774–4963

HOMERSHAM, S. C. (12th March 1868) - *Page* 406
Particulars as to various works erected by him for supplying spring water softened by Dr. Clark's process; and as to the supply generally from chalk springs and wells - - *Question* 4762–6837

JACKSON, JOHN (6th June 1867) - - *Page* 279
On the water supply of Sheffield - *Question* 4964–71

JUBB, SAMUEL (20th June 1867) - - *Page* 299
Comparison of hard and soft water as used in the cloth manufacture - - - *Question* 5320–95

LEACH, S. W. (30th May 1867) - - *Page* 250
On the volume of water in the Thames, *Question* 4240–70
Proposed store reservoirs in the upper part of the river - - - - - 4271–86
Improvements in the river; proposed exclusion of the town sewage; self-purification of the stream, 4287–99
Further remarks on the volume in the Thames, and its proposed increase by store reservoirs - 4300–20

LETHEBY, Dr. HENRY (29th May 1867) - *Page* 232
Analysis of the London waters - *Question* 3859–69
Qualities of Loch Katrine water - - 3870
On peaty water - - - - 3871–2
Pump waters in the city of London - - 3873–9
Opinion as to the general quality of the waters supplied to London - - - - - 3880–7
Purification of the Thames by exclusion of the sewage - - - - - 3889–91
Self-purification of rivers generally - - 3892–7
On the spread of cholera by drinking water 3898–3918
Water supply to various provincial towns, and its effect on their rate of mortality - - 3918–26

Quantity required per individual - - 3927–30
Comparison of soft and hard waters - 3931–42
Increase of London supply - - - 3943–46

McClean, J. R. (27th June 1867) - - *Page* 307
Information as to the project of witness and the late Mr. Blackwell for supplying London with water taken from the Thames at Medmenham, and for improvements in the river incident thereto *Question* 5498–5586
On the constant service system; particulars as to the supply by witness of towns in Staffordshire, 5587–5636
Sufficiency of the Thames for the supply of London, 5637–8
Hardness and softness in water - - 5638–42
Proportion of rainfall available in Thames basin 5643–5
Further particulars as to his Thames project 5646–52
Do. as to his Staffordshire waterworks - 5653–71
Hard and soft water - - - 5672–5
Improvements of the Thames - - 5676–82
On the supply of provincial towns generally in the Midland districts - - - - 5683–5714
Quantity and quality of water in the Thames 5715–22
Comparison of water from different strata - 5723–8
Supply to the Midland counties - 5729–35

Macneill, Telford (27th June 1867) - *Page* 320
Explanations as to his proposed scheme for supplying London, by diverting water from the Thames, and filtering it through the Bagshot sands, *Question* 5815–5958

Meeson, Rd. (18th March 1868) - *Page* 419
Information as to large springs existing in chalk pits belonging to witness at Gray's Thurrock, Essex, *Question* 6863–7

Miller, Dr. W. A. (5th March 1868) - *Page* 436
Comparison between soft and hard water, *Question* 7045–58
Peat in water - - - - - 7059–61
Sewage in water; self-purification of rivers; condition of the Thames - - - - 7062–71
Nitrates in water, as evidence of sewage contamination - - - - - 7072–7
Application of sewage on land - - 7078–80
Sewage in water - - - - 7081–4
On the constant service system - - 7085–6
Power of soft water to absorb gases - - 7087
Self-purification of streams - - - 7088–9
Effect of filtration - - - - 7089–90
Peat in water - - - - 7091
Aeration of water - - - - 7092–3
Most essential conditions for drinking water 7094
Hardness and softness - - - 7095–7
Nitrates in water - - - - 7098–7103
Modes of analysis - - - - 7104–16
Action of soft water on lead - - 7117–21
Effect of manured lands in the chalk districts - 7122–3
Hardness and softness - - - 7124–6

Morris, W. R. (26th February 1868) - - *Page* 333
Particulars as to the supply furnished by the Kent Waterworks Company - - *Question* 6094–6149
On the constant service system - - 6150–6160
Consumption per head - - - 6161– 8
Nitrates in water - - - 6169–71
Further remarks on the Kent waterworks - 6172–90

Muir, James (29th May 1867) - - *Page* 239
Particulars as to the New River Company; their supply to London, &c. - *Question* 3947–4025
Dr. Clark's softening process - - 4026–8
Capability of the Lea and the Thames for yielding increased supplies - - - 4029–53
On the constant service system - - 4054–77
Analysis of water from Amwell well (at end of evidence).

Mylne, R. W. (6th June 1867) - - *Page* 279
On the supply of London by the New River Company - - - - *Question* 4972–82
Explanations as to witness's project for increasing and remodelling the supply obtainable from the basin of the river Lea - - - - 4983–5054

Odling, Dr. Wm. (27th February 1868) - *Page* 356
On the quality of waters in the Welsh and Lake districts - - - *Question* 6433–6
Comparison between hard and soft waters - 6437–9
On the Welsh and Lake waters (*continued*) - 6440–6
On the sewage in the Thames water, and the self-purification of rivers - - - 6447–58
Nitrates in water - - - - - 6459–62
On the general quality of the water supply from the Thames basin - - - - 6463–7
On organic impurities in water - - 6468–84

Ormsby, A. S. (5th June 1867) - - *Page* 257
Particulars as to his project for supplying London with drinking water collected from the rainfall on non-absorbent artificial surfaces - *Question* 4443–4560

Orton, Thos. (30th May 1867) - - *Page* 248
On the cholera epidemic in the east of London in 1866, and its connexion with the water supply, *Question* 4172–4239

Parkes, Dr. E. A. (9th May 1867) - - *Page* 194
Communication of diseases by drinking water containing sewage - - - *Question* 3111–23
Comparison between hard and soft water - 3124–38
Action of soft water on lead - - 3139–42
Filtration - - - - - 3143–6
Classification of potable waters - - 3147–51
Character of the London water - - 3142–61
Constant service system - - - 3162–9
Communication of diseases by water - 3169–76
Quality of the water of the Thames - 3177–88
Changes in water by flowing through long conduits, 3189
Communication of diseases by water - 3190–4
Self-purification of the river Itchen - - 3195–9
Influence of the water supply on the health of troops; comparison in this respect of hard and soft waters, 3200–18
Supply of Southampton - - - 3219–20
Quantity of water per head required by troops 3221–7
On the quality of Thames water; effect of exclusion of the sewage - - - - 3228–37
Influence of different qualities of water on health; hard and soft water - - - 3238–55

Playfair, Dr. Lyon, C.B. (10th April 1867 - *Page* 156
General quality of the water supplied to London, 2634–45
Comparison between hard and soft water 2646–2719
As to the constant service system - - 2720–4
Action of soft water on lead pipes - - 2725
Influence of water supply on the mortality of towns, 2726–8

Quick, Joseph (26th February 1868) - - *Page* 328
Particulars as to the supply given by the Grand Junction Company - - *Question* 5982–6004
Increase possible from the Thames - - 6005–8
Quality of the water - - - 6009–10
On the constant service system - - 6011–56
Cost of pumping - - - - 6057–8
Quantity consumed per head - - 6059–63
Filtration - - - - - 6064–9
Further remarks on the constant service system 6070–93

Ramsay, Professor A. C. (13th March 1867) - *Page* 104
Geological character of the Welsh district *Question* 1707–12
Peat therein - - - - 1713–20
General nature of land surface - - 1721–29
Mineral workings in the district - - 1730–42
Nature of the district of Bala Lake - - 1743–8
Further particulars as to the strata in the Welsh district - - - - - 1749–71
On the district of the Cumberland lakes - 1772–6
On the Welsh district (*continued*) - - 1777–81

Rawlinson, Robert (6th March 1867) - *Page* 81
His engineering experience - *Question* 1306–22
On the formation of reservoirs - - 1323–5
Observations on the Welsh project, the rainfall, &c. 1326–42
Comparison between hard and soft water - 1343–7
On the proposed Welsh reservoirs - - 1348–58
On the quality of the Thames water - 1359–60
Hard and soft waters - - - 1361–80
On the supply of Liverpool from Bala Lake 1381–1423
Hard and soft water - - - - 1424
General conditions of rainfall - - - 1425

Second Examination (7th March 1867) - *Page* 87
On the nomenclature used in questions of water supply - - - - *Question* 1426
General conditions of rainfall - - 1427–38
Supply of Liverpool - - - - - 1439
On rainfall - - - - - - 1440
On the construction of reservoirs - - 1441–7
On rainfall - - - - 1448–52

Third Examination (13th March 1867) - *Page* 113
On the action of soft water on wrought-iron pipes, *Question* 1894–1909
On the quantity delivered by pipes of certain sizes, 1910–11
On the waste of water by defective fittings - 1912

REMINGTON, GEORGE (5th June 1867) - *Page* 253
Particulars of his project for supplying London from the river Dove in Derbyshire *Question* 4321–4442

RENDLE, W. (11th March 1868) - - *Page* 404
As to the defective supply of water in the borough of Southwark, and the necessity of the constant service system - - - - *Question* 6749–61

SIMON, JOHN (8th May 1867) - - *Page* 165
On the supply to the City of London *Question* 2737–44
On the constant service system - - 2745–50
Pollutions of the London water, and their effect in producing disease - - - 2751–64
Action of soft water on lead - - 2765–6
Constant service system - - - 2767–76
Comparison between soft and hard water - 2777–94
Filtration of London waters - - 2795–7
Quantity of water required per head - 2798–2803
On the general quality of the supply to London, 2804–26
Constant service - - - - 2827–33
Hardness and softness - - - 2834–6
On the interception of sewage from the Thames, 2837–42
Constant service - - - - 2843

Second Examination (26th March 1868) - *Page* 440
On an outbreak of typhoid fever at Guildford, believed to be caused by impure drinking water, and on the control of water companies in general, *Question* 7127–34
Effect of sewage in water; self-purification of streams, 7135–48

SIMPSON, JAMES (5th June 1867) - - *Page* 261
On the present supply of water from the Thames, and the general eligibility of the river for the future supply of London - - *Question* 4561–4611
Remarks on the Welsh project - - 4612–10
On the constant service system - - 4621–22
Quality of the London water - - 4623–37
Exclusion of sewage from the Thames - 4638–9
Future quantity derivable from the Thames 4640–51
Powers and operations of the Thames Conservancy Board - - - - - 4652–55
Sewage in the Thames - - - 4656–70
Rainfall in the Thames basin - - 4671–7
Quality of the Thames water - - - 4678–85
Objections to Welsh project - - 4685–91
Analysis of London waters - - - 4692–7
The constant service system; difficulties with it in America - - - - - 4698–4717
Quantity required for London - - 4718–22
Soft and hard water; supply of Aberdeen and Paris - - - - - 4723–32
Filtration - - - - - - 4733–4
Separation of supplies for different purposes 4735–8
The Registrar-General's reports on London waters, 4739–40
Distribution of water in London - - 4741–3
Supply to the poor - - - - 4744–50
Action of soft water on iron and lead - 4751–8
Quantity required for London - - 4759–64
Volume of the Severn - - - 4765–9
Rates for water - - - - 4770–3

SMITH, Dr. R. ANGUS (2nd April 1868) - *Page* 445
On the examination of drinking waters as regards organic matter: example from the Clyde 7183–95
Self-purification of streams - - 7196–7200
Safety of water once affected with sewage - 7201–3
Application of sewage to the land - - 7204–7
Further remarks on organic matter in water 7208–11
Peat in water - - - - - 7212–4
The Thames as a source of supply - - 7215–7
Hardness and softness in water - - 7218–22
Fouling of water in cisterns - - - 7213–8
Further remarks as to organic matter in waters 7229–58
Comparison of hard and soft waters - 7259–65
Action of soft water on lead - - 7266–8

SYMONS, GEORGE JAMES (14th February 1867) *Page* 34
On the rainfall in the Lake district of Cumberland and Westmoreland - - *Question* 434 to 466
On the rainfall in North Wales - - 467–506
Ditto in the Lake district; on evaporation, absorption, &c. - - - - - 507–525
Ditto in Wales - - - - 526–545

Second Examination (10th April 1867) - *Page* 161
On the rainfall in Mr. Bateman's Welsh district, *Question* 2729–36

TAYLOR, JOHN (9th December 1868) - - *Page* 480
Quantity of water supplied to London during the summer months of 1867–8 *Question* 7458–9
Effects of the drought of 1868 on various towns supplied by gravitation - - - 7460–89

THORPE, JONATHAN (27th June 1867) - *Page* 316
Quantity of water taken from the Thames by the London companies - - - *Question* 5736–46
Additional quantity which might be obtained by improvements in the river - - - 5767–59
Powers of the Conservancy Board for purifying the Thames, and manner in which they have been carried into execution - - - - 5760–93
General improvements of the river - 5794–5814

WANKLYN, Professor J. A. (20th June 1869) - *Page* 301
Results of chemical examination of the waters supplied to London - - - *Question* 5396–5417
On the processes of analysis for organic matter, with description of a new process used by the witness, and comparison with other methods - - 5418–40
Constant service - - - - 5441–2
Further remarks on the London waters - 5443–51
Further remarks as to mode of analysis - 5452–82
Self-purification of streams - - - 5482–7
Hardness and softness in water - - 5488–97

WAY, JOHN THOMAS (7th March 1867) - *Page* 90
Analysis of water from the Lake district, *Question* 1453–79
On waters from Wales - - - 1480–83
On the geological strata most favourable for water collection - - - - - 1484–8
Action of soft water on lead pipes - - 1489
Ditto on iron pipes - - - - 1490–8
Comparison between hard and soft water 1499–1520
On the pollution of rivers by manufactories - 1521–8

WHALLEY, G. H., M.P., (20th March 1867) - *Page* 119
General remarks on the Welsh project, and on the district forming the gathering ground for the same - - - - *Question* 2041–7
Mineral workings in the district - - 2048–65
Further remarks on the project generally - 2066–96

LONDON:
Printed by GEORGE E. EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.